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SPEAKER IDENTIFICATION TECHNOLOGY

Booz-Allen & Hamilton, Inc.

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13. ABSTRACT (Maximum 200 words)

The purpose of this effort was to explore speaker identification algorithms for military applications. Previously developed algorithms have not been robust to the short, noisy transmissions generally found in military operational communications. New and energing technologies were evaluated and some basic assumptions of current speaker identification technology were reevaluated. The most important notion challenged was that high performance speaker identificaion is not possible with very short training utterances (e.g., 5 seconds).

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1.0 Executive Summary

1.1 Overview

The purpose of this program was to explore algorithms for operational speaker identification systems. Algorithms developed in the laboratory have not been robust to the short, noisy transmissions generally found in operational communications. Because of these reasons, we evaluated new emerging methods and reevaluated some basic assumptions in speaker identification technology. The most important notion we challenged was that high performance speaker identification was not possible with very short training utterances of approximately five seconds.

Our approach was to compare traditional speech parameters with new parameters obtained from auditory-like models. Recent reported performance improvements in automatic speech recognition systems using auditory-like models motivated the approach [1] [2]. The results of these recent research efforts suggest that auditory-like models lessen the detrimental effects of noise and non-stationary channels. In addition to the parameter comparative analysis, we compared a well known clustering classifier called, the LBG Vector Quantizer, with the backpropagation and recurrent backpropagation neural network classifiers. Primarily, in the classifier study, we wanted to determine whether the recurrent network could learn a speaker's unique spatio-temporal patterns for enhanced speaker identification performance.

We used two speech databases to evaluate the developed speaker identification algorithms. We used the KING database, commonly used in speaker identification research, to baseline algorithm performance. The second database we used, the GREENFLAG database, is comprised of recordings of off-the-air transmissions of US Air Force pilots in Green Flag exercises at Nellis Air Force Base. We used the GREENFLAG database to test the developed algorithms in as close to an operational environment as possible.

1.2 Summary of Results and Their Significance

One of our main findings is that there is no single speech parameter that consistently captures the discriminating features of a speaker's voice. The channel characteristics of the communications medium dictate what parameters

and parameter normalization techniques should be used for optimal discrimination.

Once we established the best set of parameters for a given channel condition, we used a simple but effective parameter fusion method that increased overall performance. The combination of finding the appropriate set of parameters for the given channel, and then fusing those parameters during classification was the key to high performance speaker identification.

We also found that the simple vector quantizer outperformed the neural network classifiers we studied. Another drawback to the backpropagation neural networks is the amount of training time they require for achieving good performance. The neural networks we investigated took days to train. The vector quantizer, on the other hand, required only tens of minutes to train.

In the baseline experiments we were able to match or exceed published results. With a commonly used 26 speaker subset of the KING database, we were able to attain 100% recognition. Most importantly, we achieved nearly 96% recognition of 41 pilots using a total of 159 test transmissions in GREENFLAG database experiments. We obtained this performance with an average training transmission length of 4.2 seconds and an average testing transmission length of 2.4 seconds.

These results are very encouraging. We believe that high performance tactical and strategic operational speaker identification systems can be developed with the available algorithms and commercially available computational platforms. Portable field units can be deployed in less than three years.

2.0 Introduction

2.1 Organization of the Report

This report is written in three main parts and in three levels. The first part is a high level description of the effort and is found in the Executive Summary in Section 1. The second part is comprised of Sections 2-5 and describes the research effort in more detail. We omitted mathematical details in the second part to ensure clear conceptual discussions free from mathematical language. Mathematical descriptions, however, are necessary for those interested in the details of all algorithms developed or used in this effort. These mathematical details are found in Appendix 1-6, which comprise the third part of the report.

In Sections 2-5 we emphasize the details and methods we investigated that should be considered in an operational development program or that consistently produced the best results. We omitted, for example, results obtained from the neural network classifiers. Rome Laboratory personnel de-emphasized the neural network approaches and directed us not to pursue these approaches further. This does not mean, however, that neural networks should be excluded from further speaker identification research. For a detailed description of all our work, refer to the four status reports compiled in Appendix 8.

In Section 3 we describe our approach to the research in more detail. We describe the speech parameters investigated, the VQ classifier used, and the method for fusing partial results from multiple classifiers. We also discuss the open set issue in detail and describe in conceptual terms the out-of-set metrics used in the effort. We provide the results and their significance in Section 4. Section 5 is the conclusion section where we provide the lessons learned, discuss the major outstanding issues, and provide several recommendations for the next step. The references are found in Section 6. Selective result print outs are found in Appendix 7. Appendix 8 is a compilation of the four status reports delivered under this effort and Appendix 9 is the software user's manual.

2.2 Purpose of Research

The purpose of this research was to explore algorithms for operational speaker identification systems. The operational communications environment is very different from the laboratory environments in which speaker identification

technology was developed. The operational communications environment is characterized by short (typically less than 10 seconds), noisy transmissions and exhibit a great deal of channel variability. Until very recently, the laboratory produced wide bandwidth recordings of speech with high signal-to-noise ratios, which were typically tens of seconds even minutes long for each speaker. Mainly due to the disparity between the two environments, speaker identification systems have not performed well in the operational environment.

2.3 *Statement of Work Review*

Given the motivation for the research, this section briefly reviews the key tasks in the Statement of Work (SOW). The first task was to evaluate the auditory-like model of hearing, called the Perceptual Linear Prediction of speech, and the traditional cepstrum (and its variations). The second task was to evaluate the recurrent backpropagation network, at least one other neural network classifier, and the Gaussian mixture classifier. The performance of the speaker identification algorithms developed from Tasks 1 and 2 were to be tested using the KING database in Task 3.

As work proceeded, an operational database became available, the Rome Laboratory developed GREENFLAG database. Since the KING database has been widely used in speaker identification research, baseline performance tests using the KING database (for apples-to-apples comparisons) were still necessary. However, with the GREENFLAG database, we had the opportunity to test all algorithms with real US Air Force communications. Therefore, Rome Laboratory personnel directed us to test our algorithms with the new database.

In addition to this minor change, we omitted a full evaluation of the different neural network classifiers. Early in the research we attained very high recognition rates in KING database experiments using the well known vector quantization (VQ) classifier. The VQ classifier also produced very good results in GREENFLAG database experiments. Initial results using the recurrent backpropagation network and the standard backpropagation network were not as encouraging. Because of these reasons, and per Rome Laboratory's instructions, a full evaluation of the neural networks listed in Task 2 of the SOW was not conducted.

3.0 Approach

3.1 Speaker Recognition Algorithm

In this section we provide a high level description of the individual parts of the speaker recognition algorithm. The algorithm is comprised of two main systems: the training system and the performance system. Each system uses the same signal preprocessor and parameter extraction algorithms. The block diagram in Figure 1. illustrates the algorithm at the highest level.

In the preprocessing stage, the sampled communications transmission is segmented with a window of a predetermined type and length. These windowed segments are typically referred to as frames. The frames may be overlapped by a predetermined amount. In all our experiments we used a 256 sample Hamming window with 50% overlap. With 8 kHz sampled data, this amounts to a 32 msec. frame that advances in steps of 16 msec. over the sampled input signal.

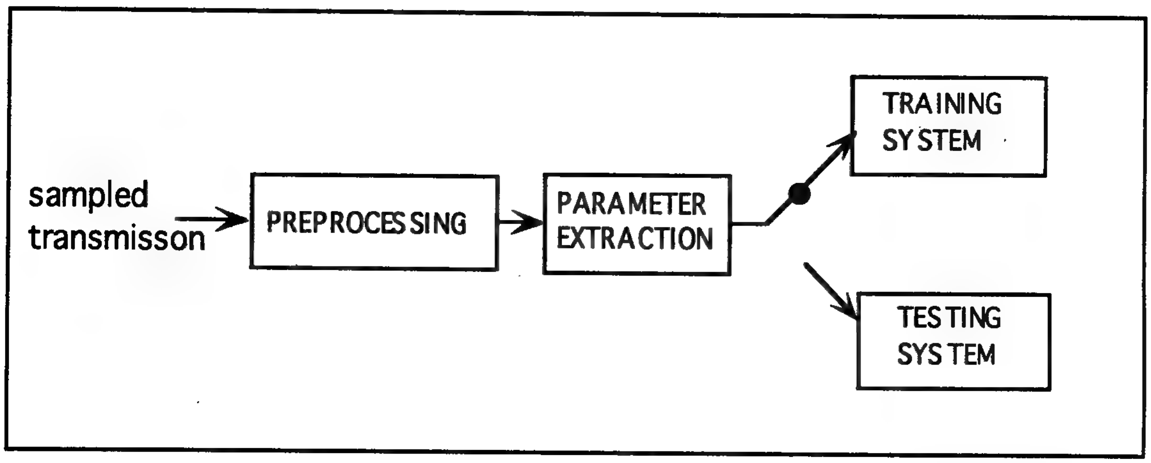

Figure 1. Block Diagram of Speaker Identification Algorithm in Training Mode

After the signal is segmented, the next step in the preprocessing stage is to determine whether the frame contains speech (specifically, voiced speech) or background noise. If the speech/non-speech detection sub-system detects speech in the frame, it passes the frame on to the parameter extraction stage, otherwise it discards the frame. Figure 2. shows the block diagram of the preprocessing stage.

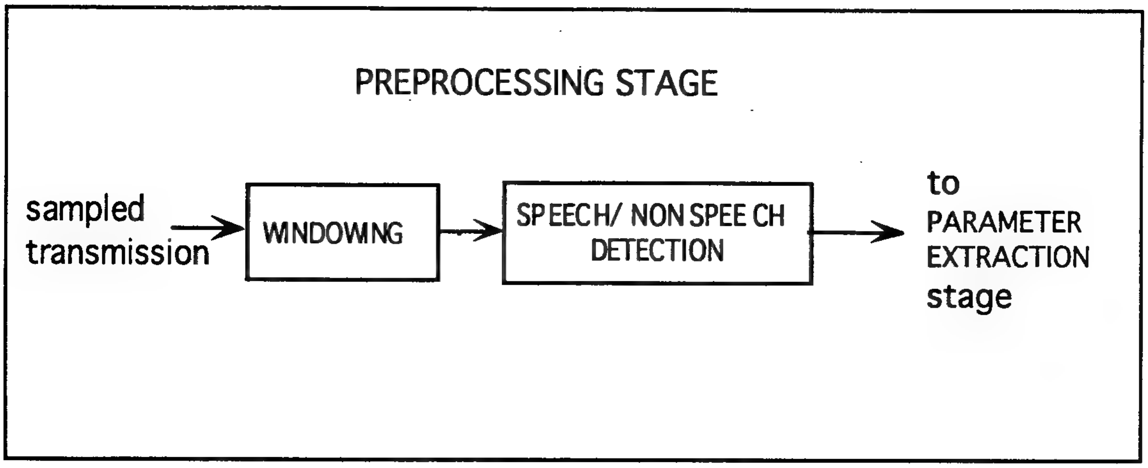

Figure 2. Block Diagram of the Preprocessing Stage

Each windowed frame containing speech is processed in the Parameter Extraction stage. After the parameters are extracted form the speech frames, they are either passed to the training sub-system or the testing sub-system depending on the mode of operation.

3.2 Speech Parameters

We describe all parameters produced by the Parameter Extraction stage in this section. We investigated two main groups of parameters. The first group is based on the Linear Predictive Coefficient (LPC) cepstrum. The LPC cepstrum is widely used in speech processing because it is easy to compute and because it performs reliably in speech processing applications [3]. The second group of parameters is based on the Perceptual Linear Prediction (PLP) cepstrum [1]. By themselves, the LPC and PLP cepstra are not robust in varying channel conditions. Therefore we chose two parameter normalization procedures and two cepstral extensions that have improved both speaker identification and speech recognition performance. These include RASTA filtering, liftering, the delta cepstrum, and the acceleration cepstrum [2] [4].

The block diagram in Figure 3 illustrates the operations of the Parameter Extraction stage. We describe each of the parameters and the normalization techniques in more detail in the following paragraphs.

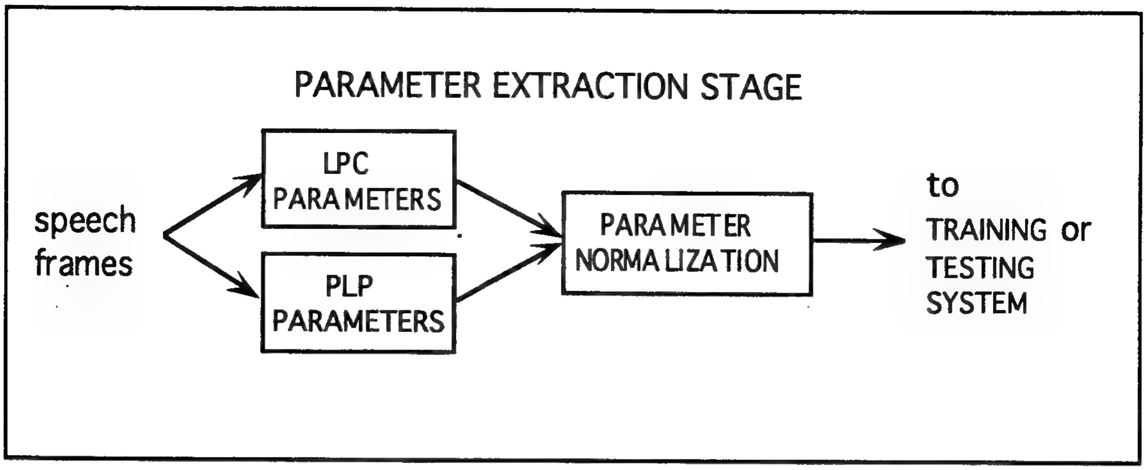

Figure 3. Block diagram of the Parameter Extraction Stage

3.2.1 Linear Prediction Coefficients. The current sample of a discrete time signal can be estimated as the weighted sum of a number of previous samples of the signal. If one could find the values of the weights in that sum that minimize the error between the value of the current sample and the estimate, then we have coefficients that can *predict* the current sample. Thus the name Linear Predictive Coefficients. There are two main reasons why the LPC characterization of speech has been ubiquitous in speech processing in over 20 years. The first reason is that the LPCs compactly describe the spectrum of the signal. The second, and equally important, reason is that the LPCs are computed quite easily. The LPCs are computed by solving a system of linear equations using the lagged autocorrelation values of the signal. The LPC algorithm and its proof is found in Appendix 1.

Notwithstanding the LPC's popularity, the cepstrum has become the speech representation of choice in both speaker and speech recognition applications (see May 24, 1993 Status Report, pg. 10). Even so, the LPC continues to play a dominant role as explained in the next section.

3.2.2 LPC Cepstrum. In this section, we summarize some important historical aspects of the cepstrum and how it is computed from the LPCs. For a more detailed treatment of the cepstrum see [5] and [6]. The cepstrum was developed in the early 60s as a tool for separating or analyzing convolved signals with different and unknown harmonic contents. In the case of speech, the cepstrum provided a method for separating the rapidly varying glottal information from

vocal tract filter or *vice versa.* This is accomplished by taking the Fourier transform of the log of the Fourier transform of the signal. In the resulting cepstrum, high frequency harmonics are visible at the low end of the abscissa, or *quefrency* axis. On the other hand, low frequency harmonics are seen as high quefrency spikes.

The cepstrum provided a new tool for applications such as pitch detection, glottal pulse analysis, and formant analysis. Pitch analysis is straightforward in the cepstrum. A dominant spike is observed in the quefrency region associated with the human's pitch range. Since the quefrency is in units of time, the inverse of quefrency describes the fundamental frequency of the harmonic. For glottal pulse and formant analysis, simple windowing techniques (or *liftering*) and the inverse cepstrum is all that is required.

In the early 70s the cepstrum was derived from the LPCs [7]. Because this method of computing the cepstrum is more efficient than the Fourier Transform approach, the LPC derived cepstrum became more popular. Because of its importance, we include the derivation of the cepstrum from the LPCs in Appendix 1. The LPC cepstrum's popularity is still strong today despite the fact that Davis and Mermelstein showed [3] that the Fourier cepstrum (especially the mel cepstrum) outperformed the LPC cepstrum in continuous speech recognition. Davis and Mermelstein found that the LPC cepstrum produced more errors than the Fourier cepstrum in the unvoiced areas of speech. This is not a surprising result since it is well known that the LPCs have difficulty modeling unvoiced speech. Since we used a voiced/unvoiced detector in most of our experiments, we assumed that the LPC cepstrum would perform as well as the Fourier cepstrum. The Davis and Mermelstein article supports our assumption.

3.2.3 Perceptual Linear Prediction. The LPC cepstrum is the speech representation of choice in contemporary speech processing applications. Recently, however, the PLP cepstrum has gained some popularity. In the search for more robust representations of speech, some in the community are studying auditory models of speech. Some of these auditory models are very complicated and require significant computational resources. For example, some of these models include fluid and basilar membrane dynamics as well as hair cell activation described as nonlinear differential equations. Hermansky [1] took a

different approach and developed a modeling technique guided by some important but loosely followed psychophysiological constraints together with well understood and efficient signal processing techniques.

The PLP modeling process begins with a straightforward Fourier filter bank representation of speech. The filter banks, however, are carefully designed to meet certain auditory psychophysiological criteria. From the filter bank representation, autocorrelation-like coefficients are computed using the inverse Cosine transform. These autocorrelation-like coefficients are then used in the LPC routine for computing *Perceptual Linear Predictive* coefficients. With these PLP coefficients, the PLP cepstrum is then computed as described in Section 3.2.2, and in greater detail in Appendix 1. We describe the PLP process in detail in Appendix 2.

In the next section, we describe how to normalize and extend the LPC and PLP cepstra in order to make the speech parameters more robust in changing channel conditions.

3.3 Speech Parameter Normalization

We used two parameter normalization techniques and two cepstral extensions that are commonly used in contemporary speech processing research. The two normalization techniques are cepstrum liftering and RelAtive SpecTrAl (RASTA) filtering [2]. The two cepstral extensions are the delta cepstrum (the first derivative of the cepstrum) and the acceleration cepstrum (the second derivative of the cepstrum). Figure 4 illustrates the Parameter Normalization stage of our speaker identification algorithm. The numbered arrows at the bottom of Figure 4 correspond to the combination of normalization techniques performed on the LPC or PLP cepstra in the Parameter Normalization Stage. Table 1 lists these combinations. Note that the DERIVATIVE block in Figure 4 has two feedback lines from its output with a number one within the feedback loop. These feedback loops signify that the delta cepstrum is fed back to the derivative process one time to produce the acceleration cepstrum. In the following subsections we describe the RASTA, liftering, and derivative processes.

3.3.1 Liftering. It is clear that the names *cepstrum, quefrency, and liftering* are clever word plays on their Fourier analogs spectrum, frequency, and filtering.

Functionally, the two groups are indeed analogs of one another. To filter a signal one multiplies the signal and filter together in the spectral domain. Similarly, to lifter a signal one multiplies the signal and lifter in the cepstral domain. Liftering therefore is a particular weighing of the cepstrum. Liftering can be used for two different purposes. In our introduction of the cepstrum, we suggested that we could use liftering for separating different parts of the speech waveform; for example, the glottal information from vocal tract filter. This is the classic use of liftering. Liftering is also used as a means of computing a weighted distance. In this study we use the Euclidean metric; therefore, liftering is used to compute the weighted Euclidean distance between the target and test vectors. We investigated several lifters and found that the Hamming window performed the

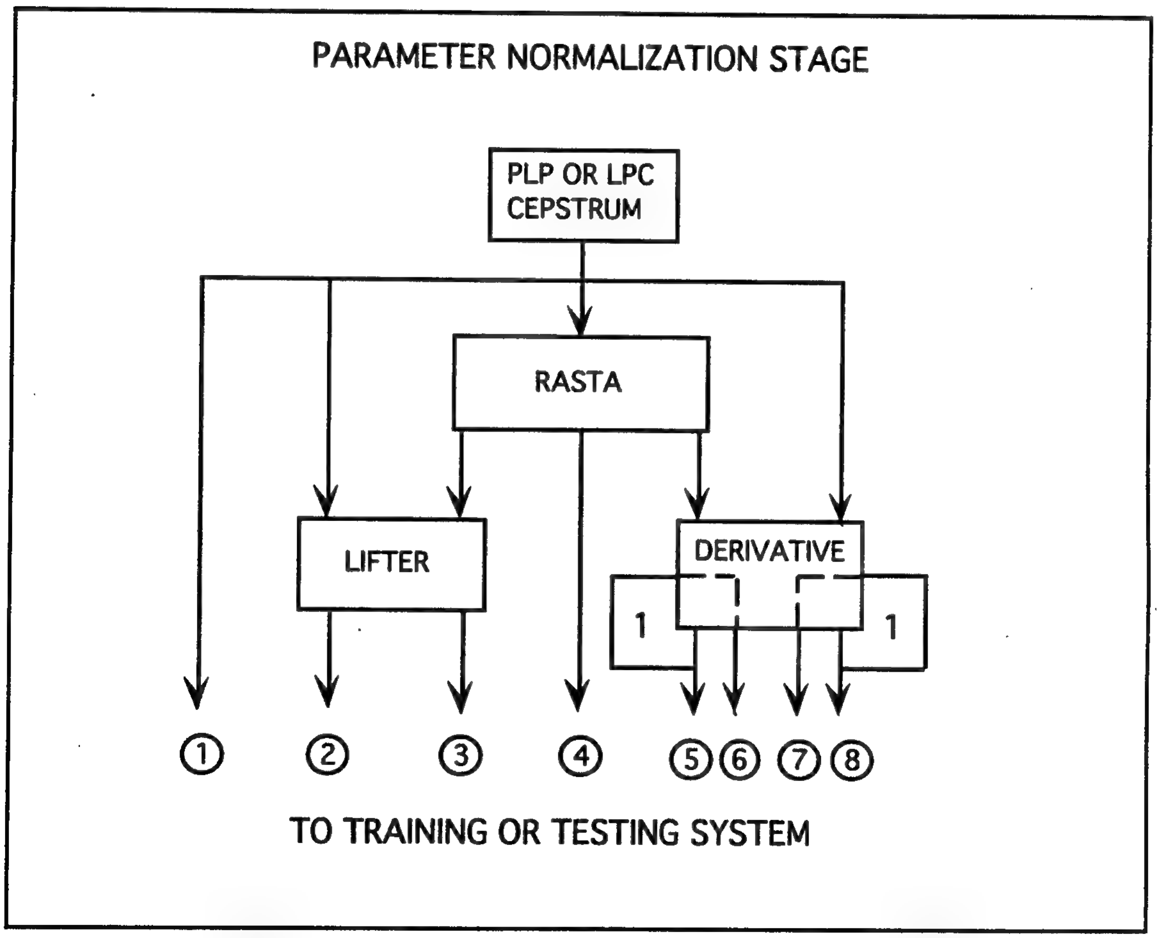

Figure 4. **Block diagram of the Parameter Normalization Stage**

Parameter Combinations

Number	Parameter
1	cepstrum
2	liftered cepstrum
3	liftered cepstrum with RASTA filtering
4	cepstrum with RASTA filtering
5	delta cepstrum with RASTA filtering
6	acceleration cepstrum with RASTA filtering
7	acceleration cepstrum
8	delta cepstrum

Table 1

best. For a more in-depth discussion on the weighted Euclidean metric for the cepstrum see [6] pp. 377-379.

3.3.2 RASTA Filtering. Simply put, the RASTA operation is the bandpass filtering of each cepstral channel (or coefficient) over time. Hermansky introduced RASTA to remove the slow varying processes induced by the channel. We included the filter details in Appendix 3.

3.3.3 Delta and Acceleration Cepstrum. The common method of finding the derivative of a sequence at a point is through an N point linear regression. Therefore, to find the delta cepstrum, we used an N point linear regression over each cepstral channel. For the acceleration cepstrum, we repeated the process on the delta cepstrum. We experimented with $N = 3$ though $N = 7$. We included the linear regression equation in Appendix 1.

After the Parameter Normalization Stage produces all parameters, they are sent to either the Training System or Testing System depending on the speaker identification algorithm's mode of operation. The training and testing sub-systems are described in terms of the Linde-Buzo-Gray Algorithm in Section 3.4.

3.4 Classifier

The classifier's training procedure defines the training system. Similarly, the testing system is defined by how the classifier is used during performance and how the output scores the classifier produces are accumulated to provide an

answer. In this section we explain how we used a vector quantization clustering algorithm for our training and testing systems.

We used a vector quantization clustering algorithm called the Linde-Buzo-Gray (LBG), or K-means algorithm, for training the VQ classifier. This algorithm is also known as the Generalized Lloyd's algorithm in the data compression literature. In short, the LBG algorithm groups the training vectors into K distinct vectors or *codewords* in such a way as to minimize the total average error between the training data and the codewords. We used the mean squared error criteria, which is same as the normalized, squared Euclidean distance. We describe the LBG algorithm in more detail in Appendix 4.

The LBG algorithm comprises our Training System. The training vectors correspond to all the cepstral parameters (of a single type) obtained from the training signal's speech frames. Thus, each speaker's training signal is passed through the Preprocessing Stage, through the Parameter Extraction Stage, and finally through the Training System. The Training System produces a codebook (a collection) of K codewords for each parameter class, for each speaker. For example, for a three parameter speaker identification system for 20 speakers, a total of 60 codebooks are generated during training. We found that 40 codeword codebooks produced the best results in both GREENFLAG and KING database experiments.

To simplify our description of the testing procedure, let us concentrate our discussion on a single codebook - for some parameter type - from some speaker. Like the training signal, the test signal is decomposed into a sequence of vectors after it passes through the Preprocessing and Parameter Extraction stages. This entire sequence of vectors is passed through the codebook and the average of all the lowest mean squared error (MSE) scores is computed. This procedure is repeated for all parameter types and for all speakers. In the next section we describe how to combine the average lowest MSE scores produced by each individual parameter codebook, from each speaker, to arrive at the final decision.

3.5 Parameter Fusion

In Section 3.3 we described eight individual parameters we compute for each frame of speech. Therefore, as per Section 3.4, there are eight possible codebooks trained for each speaker. Similarly eight different codebook scores are generated

during a test. The question is how to combine these scores meaningfully to acquire better results than can be attained by any individual parameter. We use a very simple technique. For each parameter class, we find the ratio between each speaker's score and the winning speaker's score. After all ratios are computed for each parameter class, we simply add each speaker's ratios. The speaker with the lowest ratio sum is chosen as the target speaker.

A simple example will illustrate the parameter fusion or *adjudication* process. Suppose there are three speakers (s1, s2, and s3) in the set. A codebook based on the cepstrum and a codebook based the delta cepstrum is trained for each speaker. A test signal for s2 is decoded by the two codebooks and produces the results shown in Table 2. These are typical scores encountered in real tests.

Codebook Adjudication Example

	Cepstrum		Delta Cepstrum	
Speaker	MSE	ratio	MSE	ratio
s1	.0504	1.00	.00053	1.23
s2	.0509	1.01	.00043	1.00
s3	.0723	1.43	.00081	1.88

Table 2

The ratio sums for s1 through s3 are 2.23, 2.01 and 3.31 respectively. In this example, s2 is chosen as the target speaker, which is the correct speaker. Simply adding the MSE scores directly would not have produced the correct result. The MSE ratio gives a relative measure of closeness within a given parameter space and thus provides an intuitive vehicle for combining disparate parameter codebook scores.

In our tests we found that, in most cases, multi-parameter fusion produced better results than could be attained through any single parameter. The ratio method is not the only method of combining individual classifier results.

3.6 *Significance of Open Set Classification in Operational Speaker ID*

The speaker identification problem is a classification problem where the classes are defined as the individual speakers of some predefined group or *set*. Closed set speaker identification involves only speakers from the given set of previously trained speakers. In other words, the test speaker is known to be one from the set. In this case the classifier has only to find the speaker model that best matches the test speaker. The classifier performance is based on the percentage of correct identifications.

In operational speaker identification, however, one cannot guarantee that the test speaker is in the set of trained speakers. This is an open set classification problem. The classifier must first determine whether the test speaker is one in the desired set before it tries to match speakers. Equivalently, the classifier could first match the test speaker to a potential candidate in the trained set, and then determine whether it really is the target speaker. We used the latter approach in our investigations. Classifier performance in this case is based on three parameters: percent detection (how many test speakers from the desired set were classified as in-set speakers), percent correct given detection (how many of the test speakers correctly classified as in-set speakers were correctly identified), and percent false alarms (how many test speakers not in the desired set were incorrectly identified as in-set speakers).

Open set classification is more difficult because boundaries (or score thresholds) must be determined for each speaker in the trained set. In the next section we describe the metrics we used to determine those boundaries.

3.7 *Out-of-Set Metrics*

We investigated four out-of-set metrics in this effort. These include global MSE score thresholds, individual thresholds based on the average of the N closest matching speakers' scores, cohort normalized thresholds, and thresholds based on the probability of observing a candidate speaker's score. We describe each of these in the following subsections. The mathematical details are found in Appendix 6.

3.7.1 Global MSE Score Thresholds. Just as the name implies, with this method, a global MSE score threshold T is determined for all speakers. If the candidate speaker's MSE score is greater than T the candidate is rejected; otherwise, the

candidate is accepted as the identified speaker. This is the simplest method because it requires no additional computational steps to determine the threshold. However, one would not expect that all speakers have the same optimal threshold. If this is true we need to find a method of getting the best threshold for each individual. The following metrics attempt to accomplish this.

3.7.2 N Closest Speakers' Scores Thresholds. With this metric each speaker's threshold is derived from scores produced by testing all other speakers' training signals against the given speaker's codebook. The threshold is set to the average N smallest MSE scores produced. The motivation here is to find the speakers with the acoustic characteristics that best match the speaker in question, and to set a threshold based on the scores produced by their speech. The following method uses a variation on this theme.

3.7.3 Cohort Normalized Thresholds. There is another method of finding the speakers that are acoustically closest to a target speaker. Take a given speaker's training signal and test it against all other speaker's models (or codebooks). The speaker models that produce the smallest scores are the ones acoustically closest to the speaker in question. The closest speakers in this case are known as cohorts [8]. There is a method of normalizing a candidate speaker's score using his cohort's scores. It is cumbersome to describe this method without mathematics; therefore, we describe the details in Appendix 6. Suffice it to say that if this normalized score is less than some threshold C, then the candidate is rejected; otherwise the candidate is accepted as the speaker.

3.7.4 Probability Thresholds. With this method, we want to find the probability that the scores previously produced by the candidate are greater than the current candidate's score. If that probability is less than some threshold P, then the candidate is rejected, otherwise the candidate is accepted as the identified speaker. To find the probability in question, one produces a cumulative distribution of scores obtained by testing the speaker's training signal against the speaker's codebook. The next step is to subtract that distribution from one. Upon testing, the value of the resulting cumulative distribution at the candidate's score is the probability we are looking for. The training signal must be broken up into smaller segments in order to acquire enough scores to make a probability density. Subsequent testing must be done at the same temporal scale as was used to determine the probability densities.

3.8 Summary of Approach

In Section 3 we provided an architectural and functional description of the main speaker identification system we investigated in this effort. We investigated several other parameters, classifiers, and scoring approaches that we did not include in this final report because we felt it distracted from the discussion of the best approaches for developing an operational speaker identification system. All our work is fully documented in the four status reports we delivered to Rome Laboratory.

4.0 Results

4.1 Introduction

As we previously stated, we used two databases to test the performance of the speaker identification system. Since the results of several speaker identification studies are available that used the KING database, we first performed KING database tests to make meaningful comparisons and to baseline our system. Although the KING database is not comprised of operational communications, it is made of long distance telephone communications over a variety of channel conditions. This makes the database very useful in speaker identification research for it provides an environment rich in channel diversity. Once we determined the baseline performance of our system, we tested the algorithms with Rome Laboratory's GREENFLAG database. The GREENFLAG database is comprised of tactical USAF communications during Green Flag exercises at Nellis AFB. The GREENFLAG database, therefore, is the database of choice for USAF operational speaker identification R&D efforts. In sections 4.2 and 4.3 we summarize the results from our KING and GREENFLAG database experiments.

4.2 King Database Results

4.2.1 KING Database Description. The KING database is comprised of long distance telephone recordings of 50 speakers. There are a total of 10 sessions in which all 50 speakers are represented. The sessions average approximately 40 seconds in length. The database is rich in channel variability. Sessions 1-5 and sessions 6-10 were recorded using two different recording setups respectively.

Furthermore, 26 speakers were recorded at a site in San Diego, California and the other 24 speakers were recorded at a site in Nutley, New Jersey. The Nutley recordings are much noisier than the San Diego recordings. Also, to capture variability in each speaker's voice, the different sessions were recorded over several months.

42.2 How KING Database is Used. The KING database is typically used in *strategic* speaker identification research. In strategic speaker identification, target speakers are modeled for long term identification purposes regardless of the communications medium. The usual approach in this type of speaker id is to model the speaker in as many different channel conditions as possible. In order to produce these *general* speaker models, many seconds or even minutes of speech data are required. Following this approach, most investigators that use the KING database usually use three sessions for training (or nearly two minutes of data), and use two other sessions for testing. We followed the same CONcept of OPerationS (CONOPS) or procedure in our KING experiments. Specifically we used the 26 speaker San Diego group for most of our tests. We used sessions 1-3 for training and sessions 4 and 5 for testing. We conducted only closed set experiments with the KING database.

4.2.3 Results with KING Database;. We found that the LPC based cepstral parameters significantly outperformed the PLP based cepstral parameters. The best combination of PLP parameters produced 88.5% recognition and the best combination of LPC parameters produced 100% recognition (see May, July, and November Status Reports for details). In Table 3, we summarize the results we obtained using several combinations of LPC cepstral parameters and the classifier adjudication process we described in Section 3. We show the results of only a subset of every possible combination of parameters shown in Table 1.

Table 3 is representative of the results we obtained in most KING experiments. We obtained the best results by using both parameter normalization procedures, liftering and RASTA filtering, together with the delta cepstrum extension. We also found that the acceleration cepstrum did not provide as much improvement in performance as the delta cepstrum. In Appendix 7 we include the confusion matrix outputs of selective KING database performance runs.

Summary of KING Results

Parameter Combination	Percent Correct
liftered cepstrum	76.9 %
RASTA-liftered cepstrum	88.5 %
delta cepstrum	92.3 %
acceleration cepstrum	76.9 %
liftered cepstrum & delta cepstrum	84.6 %
liftered cepstrum & acceleration cepstrum	84.6 %
RASTA-liftered cepstrum & delta	100.0 %
RASTA-liftered cepstrum & acceleration	96.2 %
liftered cepstrum, delta, & acceleration	84.6 %

Table 3

4.3 GREENFLAG Database Results

4.3.1 GREENFLAG Database Description. The Rome Laboratory GREENFLAG database is a collection of 100 hours of off-the-air tactical communications related to takeoffs and landings. For the experiments described here, transmissions from 41 speakers and 8 aircraft were used. The following table identifies the number of speakers associated with each aircraft type.

Number of Speakers in Aircraft Type

Number of Speakers	Platform Type
4	A10
1	B52
1	C130
1	EA6
4	F4G
9	F15
11	F16
3	F111

1	F117
2	RF4C
4	Towers

Table 4

The number of transmissions per speaker range from 3 to 12. The transmissions are also very short, ranging from less than a second to eight seconds, and have a wide range and level of background aircraft noise. We arbitrarily used the first two transmissions for training and all subsequent transmissions for testing. We regard the two concatenated training transmissions as a single transmission. In all we used 41 transmissions for training and 159 transmissions for testing. The following tables provide training and testing transmission lengths and statistics.

Training Transmission Length Statistics For 41 Transmissions

stat	seconds
max	8.69
min	2.10
mean	4.24

Table 5

Training Transmission Lengths

Transmission Length (*tl*)	Number of Transmissions
$2.0 \leq tl < 3.0$	6
$3.0 \leq tl < 4.0$	15
$4.0 \leq tl < 5.0$	12
$5.0 \leq tl < 6.0$	3
$6.0 \leq tl < 7.0$	3
$7.0 \leq tl < 8.0$	0
$8.0 \leq tl < 9.0$	2
Total	41

Table 6

Test Transmission Length Statistics For 159 Transmissions

stat	seconds
max	6.75
min	0.36
mean	2.35

Table 7

Test Transmission Lengths

Transmission Length (*tl*)	Number of Transmissions
0.0≤ *tl* <1.0	20
1.0≤ *tl* <2.0	77
2.0≤ *tl* <3.0	39
3.0≤ *tl* <4.0	13
4.0≤ *tl* <5.0	7
5.0≤ *tl* <6.0	2
6.0≤ *tl* <7.0	1
Total	159

Table 8

4.3.2 *GREENFLAG Database and Tactical CONOPS.* In our discussion of the KING database and its use, we introduced the term CONOPS to define how speaker identification is conducted for strategic purposes. The CONOPS for tactical speaker id is very different. In a tactical situation, on-line speaker training may be required with very limited data and subsequent identification may only be necessary during a particular mission. For example, an operator may want to track pilots on a mission-by-mission basis. With this CONOPS the background noise and channel may actually help distinguish the different pilots, especially if they fly different aircraft. In this case, parameter normalization techniques for reducing channel effects may reduce identification performance, particularly when very little data is used for training. The results we show in the next section supports our conjecture.

4.3.3 Closed-Set GREENFLAG Results. In Table 9 we show the closed-set results obtained from the 159 test transmissions. Note that RASTA filtering degraded overall performance. This result is consistent with the putative channel normalizing effects of RASTA filtering. Since we assume the acoustic background in the transmissions are helping to separate the different speakers, one would expect that channel normalization would degrade performance. Again we find that acceleration cepstrum either reduced or provided no significant performance gains.

The effects of liftering are very interesting. We found in our GREENFLAG tests, that by themselves, the cepstrum and the liftered cepstrum perform about the same. As shown in Table 9, the 91.8% recognition (for the cepstrum) versus the 91.2 % recognition (for the liftered cepstrum) represents a difference of only one misclassified transmission. However, in combination with the delta cepstrum, their effects on performance are significant. With the basic cepstrum combination only three more transmission were correctly classified. With the liftered cepstrum combination seven more transmissions were correctly classified. We include the transmission-by-transmission results in Appendix 7.

Closed-Set Identification Results

Parameter Combination	Percent Correct
cepstrum	91.8 %
liftered cepstrum	91.2 %
delta cepstrum	66.7 %
acceleration cepstrum	32.1 %
RASTA-liftered cepstrum	63.5 %
cepstrum & delta cepstrum	93.7 %
cepstrum & acceleration cepstrum	89.9 %
liftered cepstrum & delta cepstrum	95.6 %
liftered cepstrum & acceleration cepstrum	91.8 %
RASTA-liftered cepstrum & delta	74.2 %
RASTA-liftered cepstrum & acceleration	61.0 %

Table 9

4.3.4 Open-Set GREENFLAG Results. In this section we present our open-set results. We did not conduct any open-set experiments with the probability method. We decided to test a different classification scheme that uses the statistics of the output scores (see Appendix 5) rather than the scores themselves. The best results we achieved using this method was 88.5%. We hypothesize that this lower performance resulted from non-representative cumulative distributions due to insufficient data. Because of this reason we abandoned the probability metric for open-set detection in GREENFLAG database tests.

With the open-set problem, it was not clear how to best combine the results obtained from the different parameters. Our first approach was to reject the candidate speaker only when *both* cepstral and delta cepstral scores failed the threshold criteria. We found that this approach, the delta cepstrum did not provide any additional performance improvements. This is evident in operating curves shown in Figure 5 and 6. These operating curves were obtained using the *N* Closest Speakers' Scores method described in Section 3.7.2. For the Global Threshold and Cohort Threshold methods, we show the operating curves obtained from the cepstrum alone in Figures 7-10.

The operating curves in all cases were obtained by alternating each speaker as an out of set speaker. All test transmissions were then processed through the identification system in each iteration. Therefore, for each data point, 6519 (41 times 159) transmissions were processed.

It is clear from Figures 5-10 that the three out-of-set metrics produced similar results. We suggest two methods to improve performance. The first method is to find a candidate speaker by using the parameter fusion process we described in Section 3.5. Afterwards, use only the cepstral parameter for the out-of-set test. Although the false alarm rate will not improve, the detection rate should increase several percentage points (see Section 4.3.3). The second suggestion is to use a separate set of training data to find individual MSE thresholds or cohort normalized score thresholds. The single point around the 19%-82% false alarm-detection rate in Figure 9 was produced by arbitrarily using portions of each speaker's test transmissions to find individual cohort normalized score thresholds. Subsequently, we processed the rest of the test transmissions in the usual way. With this method, we improved the false alarm rate from 48% to 19% at the 82% detection rate.

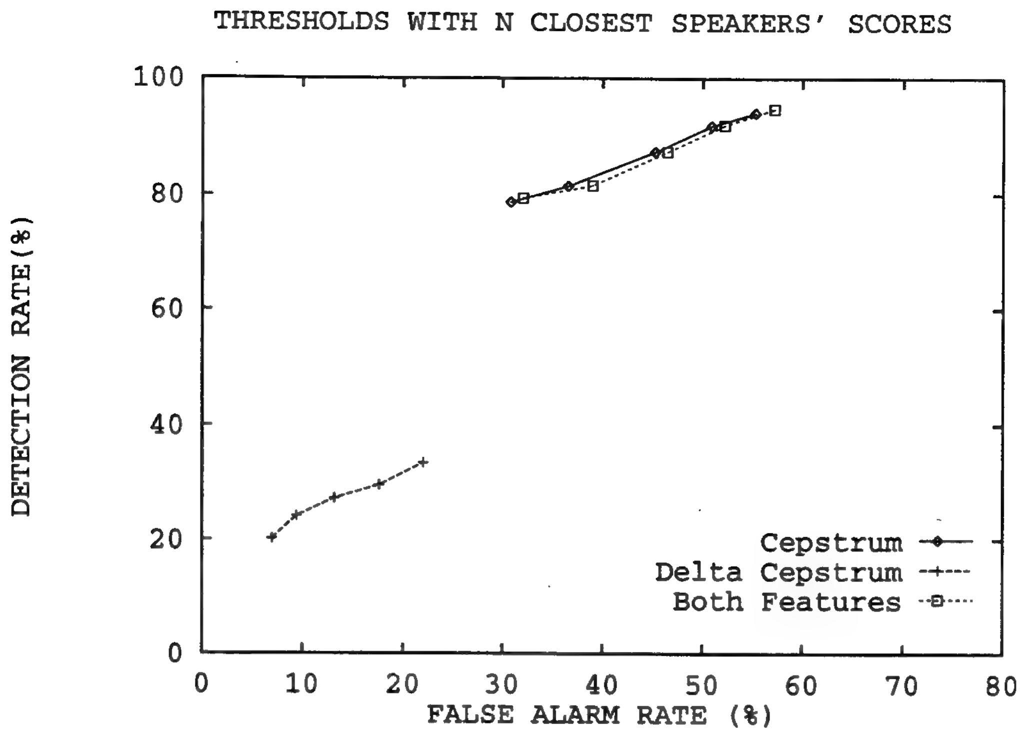

Figure 5. **False Alarm Vs. Detection Rate From *N* Closest Speakers' Scores Thresholds**

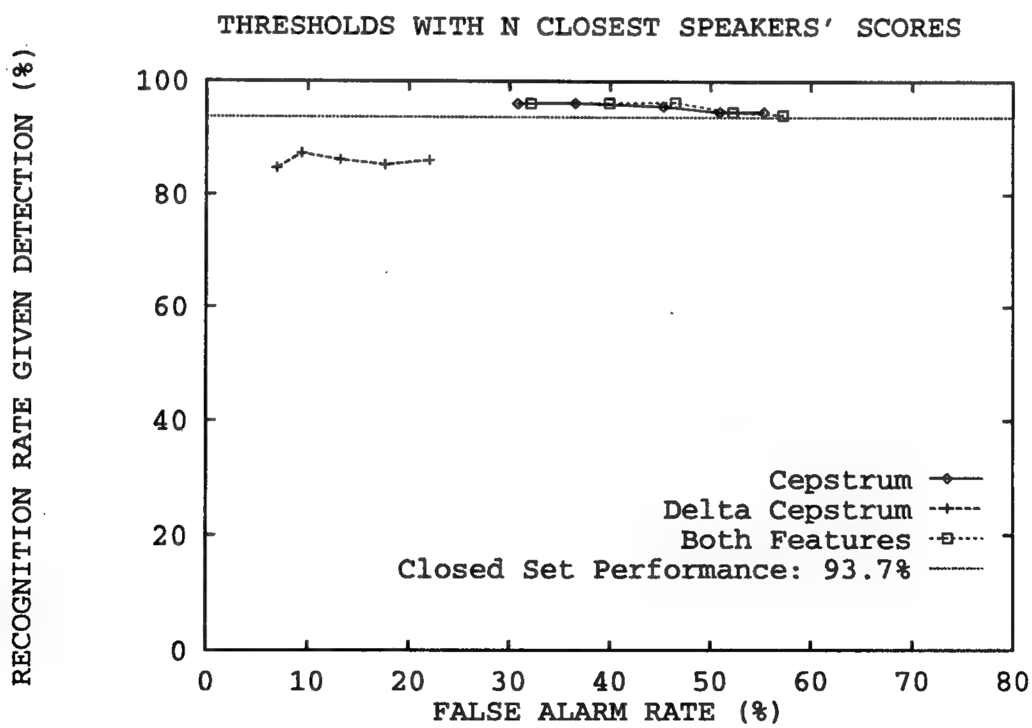

Figure 6. **Recognition Given Detection Rate Form *N* Closest Speakers' Scores Thresholds**

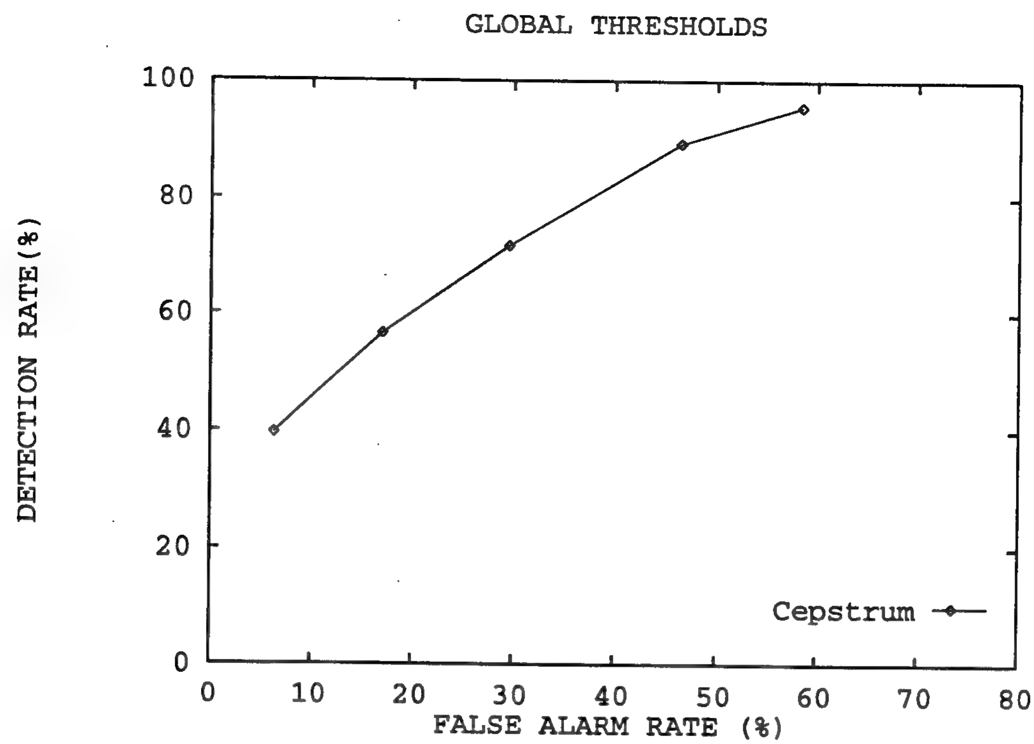

Figure 7. False Alarm Vs. Detection Rate From Global Thresholds

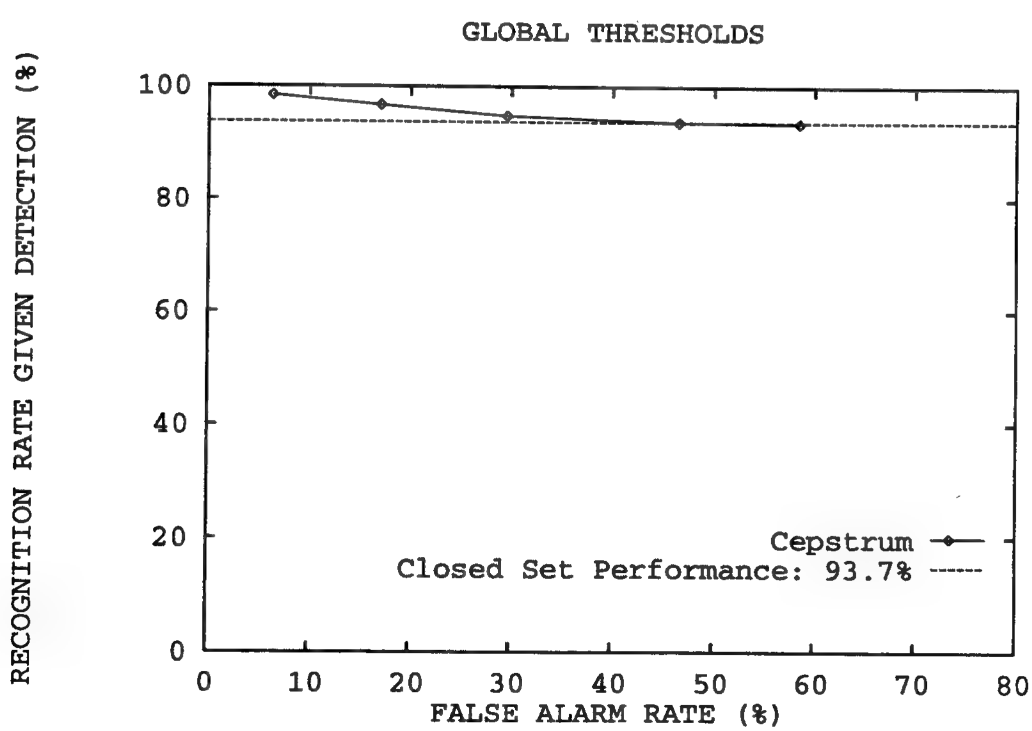

Figure 8. Recognition Given Detection Rate From Global Thresholds

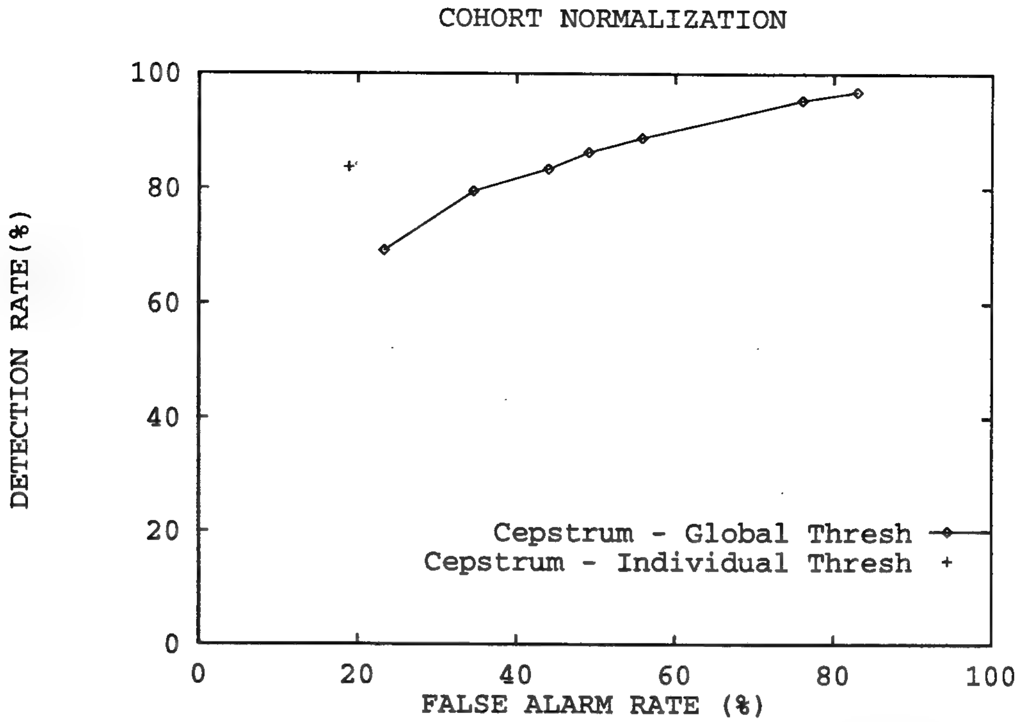

Figure 9. **False Alarm Vs. Detection Rate From Global Thresholds**

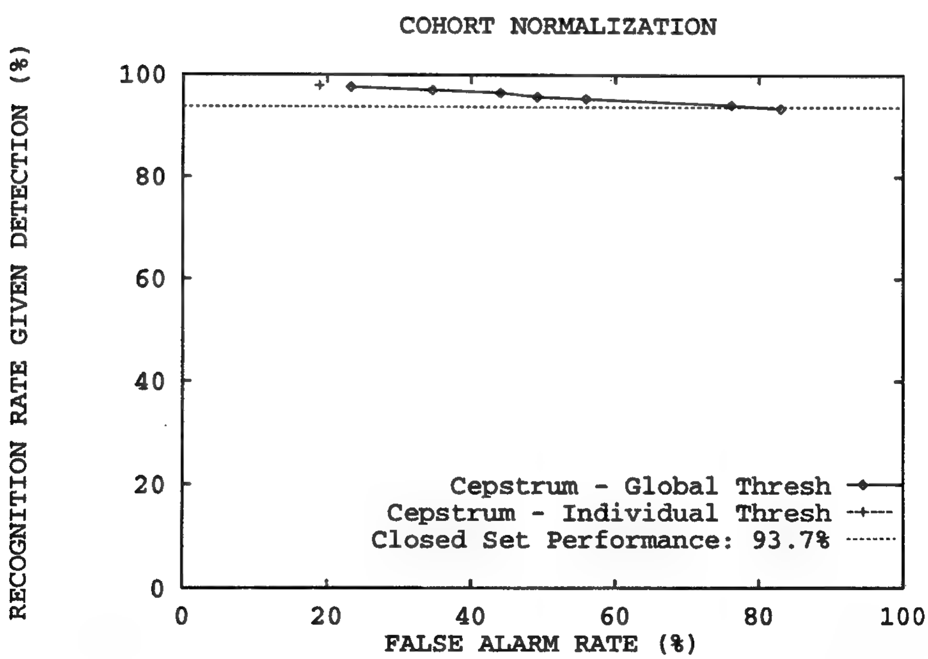

Figure 10. **Recognition Given Detection Rate From Cohort Thresholds**

4.4 *Summary of Results*

In summary, we attained very respectable results in this effort. In closed-set experiments using the 26 speaker San Diego group subset of the KING database we attained 100% recognition. This recognition rate was obtained by fusing the RASTA-liftered cepstrum with the delta cepstrum using the codebook adjudication process described in Section 3. The scenario simulated in the KING experiments is typical of a strategic speaker identification application.

In a simulated tactical environment using the GREENFLAG database, we attained 95.6% recognition of 41 pilots and air traffic controllers from 159 test transmissions in closed-set tests. We obtained this performance rate using an average transmission length of only 4.2 seconds for training and an average transmission length of 2.4 seconds for testing. In GREENFLAG open-set experiments, the best false alarm rate we obtained was 19% at a detection rate of 82%. The recognition given detection rate was nearly 99% at the 19% false alarm rate. In all GREENFLAG experiments we found that the liftered cepstrum in conjunction with the delta cepstrum provided the best results.

5.0 Conclusion

5.1 *Lessons Learned*

In this section we briefly discuss the most important lessons we learned during the course of this effort. We present these lessons in the four categories highlighted in Sections 5.1.1-5.1.4 that follow.

5.1.1 Parameters, Parameter Normalization, and Channel Effects. The parameter normalization requirements for high performance speaker identification depend on the expected communications channel conditions. The expected channel conditions are in turn dependent on the application's CONOPS. With typical strategic CONOPS, where target speakers are modeled for long term identification in a variety of communications channels, parameter normalization is necessary for better performance. Different communications channels produce different distortions in the speech parameters. Therefore, normalization inhibits these distortions and makes it easier for the classifier to correctly match acoustic features.

On the other hand, with a tactical CONOPS, in which target speakers are trained on-the-fly for subsequent mission tracking, the channel and audio background actually help the discrimination process. This occurs because the communications channels tends to be fairly constant and quite different from speaker to speaker. Because of this, channel normalization should not be performed.

We now turn our attention to the parameter and normalization details themselves. We found that in all cases the LPC cepstra produced better results than the PLP cepstra. We also found that the acceleration cepstrum actually hurt performance in some cases, and at best provided little performance improvements. The delta cepstrum, however, significantly improved performance when used in conjunction with one of the cepstral parameters. Although liftering is sometimes considered a parameter normalization technique, we found that it produced better results in the tactical GREENFLAG database experiments as well. We do not believe that liftering attenuates channel induced distortions. Instead it seems to enhance cepstral features that are important for speaker discrimination (see [6], pp. 377-379 for a discussion on the effects of cepstral liftering). RASTA filtering, on the other hand, appears to decrease channel effects as advertised.

All this is good news, for we can reduce our potential list of parameters to three: the liftered cepstrum, the delta cepstrum, and the RASTA-liftered cepstrum. Our parameter choice decisions are now also quite simple. In a strategic speaker id environment, use the RASTA-liftered cepstrum with the delta cepstrum; in a tactical speaker id environment, use the liftered cepstrum with the delta cepstrum.

5.1.2 Classifiers;. We found that the VQ performance was as good or better than the performance of the two backpropagation networks. This was one of the reasons why we discounted the networks early in the program. The other major and more important reason was that it took an inordinate amount of training time (several days) for the networks to perform well. The VQ classifier, on the other hand, trains in minutes, not hours or days. However, this does not mean that backpropagation networks should not be considered for operational speaker identification systems. Backpropagation networks may still play an important role in strategic systems where long training times could be tolerated.

5.1.3 Open Set Issues;. The main lesson we learned during our open set experiments was that the best false alarm-detection rate performance can be achieved by having a second set of training data available for setting individual speaker score thresholds. Without the second set of training data, we can expect at best a 27% false alarm rate at 80% detection. With a second training set we can expect at least a 10% reduction in the false alarm rate. In all cases the recognition rate given detection is greater than or equal to the closed set recognition rate. We claim these results constitute a worst case scenario.

We also found that we can increase the detection rate by sticking to the original speaker identification procedure. In other words, first follow the parameter fusion process as in the closed set procedure, then test for out-of-set with only the cepstral parameter threshold.

5.1.4 Training Data Requirements. The amount of training data required depends on the speaker identification CONOPS, the channel conditions expected, and the open set requirements; all issues discussed in the previous subsections. Not surprisingly, we found that in all cases the more training data available the better. In a strategic scenario, performance is greatly improved when more training data is available from various communications channels. Even when parameter normalization is used, it is important to model as many channel variations as possible. In a tactical environment, at least two sets of training data is required for good open set identification. Perhaps the most important lesson we learned in this effort was to use whatever data is available. Even with as little as a few seconds of training data in a tactical scenario, high performance speaker identification is possible.

5.2 Outstanding Issues

As in any research effort, new questions arose and a few issues remained unresolved in this effort. We present these issues in the following list:

a) We do not know how our system will perform on a large population (over 100) of speakers. It is also not clear whether large population speaker identification is really needed. It is possible that any large population application could be broken down into categories in order to reduce the set of target speakers.

b) We did not investigate signal segmentation methods for isolating speaker's transmissions. We assumed perfect segmentation in our experiments. One approach to this problem is to make speaker identification decisions within a one to two second sliding window. In this way speaker transitions can be detected. We have seen evidence that supports this approach. Our speaker identification demonstration system reports intermediary individual frame results every 300 msec. These intermediary results almost always match the final decision made at the end of the transmission. Because of this we are confident that a one to two second window is sufficient for high performance identification. We can also perform onset and offset key-click detection to segment entire transmissions if these key clicks are available in the transmissions.

c) Notwithstanding the LPC cepstrum's success in this study, there are several other speech modeling techniques that can be studied. We previously mentioned that the mel-cepstrum performed better than the LPC cepstrum in continuous speech recognition experiments [3]. Therefore, the mel-cepstrum is a good candidate for study. There are also completely different approaches, such as higher-order spectral modeling [9] and wavelet analysis [10]. These methods may be better able to model and separate out noise from the acoustics of speech.

d) RASTA filtering was the only true parameter normalization technique we studied in this effort. There are other techniques available such as the mean normalization and blind deconvolution that can also reduce channel effects. Other techniques such as Principal Components Analysis for feature extraction and discriminant analysis [11] have the potential to isolate the cepstral components that best separate the speakers. These components could also be less susceptible to channel noise [4].

e) Other classifiers need to be studied in order to determine whether classifier fusion will improve performance. A good candidate is the Ramping Adaptive Vigilance Network, or RAVN, developed by Booz•Allen in another USAF program. RAVN has a built in out-of-set detection mechanism that could be useful for speaker identification. If different classifiers are studied, other fusion techniques have to be investigated as well.

f) The out-of-set metrics we investigated were not tested in a strategic environment. We did not have the time to perform open set tests with the KING database. However, others have reported excellent open set speaker

identification results in strategic like experiments using the cohort normalization technique [12].

5.3 *Recommendations*

In our opinion, speaker identification technology and digital signal processing technology are at the stage where portable operational speaker identification systems can be developed and fielded. We believe our findings in this effort support this claim. In this final section of our report we provide our recommendations for how to proceed with a systems development program.

The first step is to define the system requirements. At a minimum, we suggest the following requirements. The proposed system should be flexible enough to handle both tactical and strategic CONOPS. The system should also be able to transition from tactical to strategic modes of operation. On-line real-time speaker training should be a required capability. New speakers should be trained without the need to retrain all other speakers.

The algorithms we discussed in this report can meet these requirements. Therefore, we suggest that the algorithms can be immediately ported to the appropriate digital signal processing platform to develop an initial prototype. We are confident that the initial prototype could perform well on its own. Improvements can be made by addressing the outstanding issues we presented in the previous section. The prototype development and the additional research can be conducted simultaneously. As improvements are found in the research, they can be incorporated into the working prototype. In this way a working prototype can be ready for testing in the first few months of the effort. Any improvements can be added throughout the life of the program.

In our opinion, one of the most important requirements we suggested was the capability to transition from a tactical to a strategic environment. A typical scenario follows. Suppose the mission is to track the communications of a group of target speakers over some unspecified period of time. Furthermore, suppose no training data is available prior to the first mission. The key is to have a two part system combined into one. The first part is comprised of a tactical system that is cleared and retrained on-line each day. The second system is the strategic system which is trained off-line but is used daily in performance mode with the tactical system. The system details are described in the next paragraph.

The tactical system is comprised of classifiers that process the liftered cepstrum and delta cepstrum of each speaker. The strategic system is comprised of classifiers that process the RASTA-liftered cepstrum (or other channel normalizing parameters) and the delta cepstrum. On each mission, the operator will train the tactical system with the first few transmissions of each target speaker. The training is done on-line, one speaker at a time. The trained speaker's classifiers can be placed in performance mode immediately after training. Therefore, the operator has the capability to track and train simultaneously. As the system identifies speakers during performance, the identified speakers' transmissions (up to a predefined number) are recorded for later use. At the end of the mission, analysts can determine which speakers were correctly identified. Their corresponding transmissions can then be used to train or retrain the strategic system. The tactical system is cleared after each mission and the process is repeated on the following mission. After the initial mission, the strategic system is used in performance mode along with the tactical system.

This process can be repeated for several missions until the analysts are satisfied that enough channel variability has been encountered and the strategic system is performing satisfactorily. After this initial set of missions - we will call it the Priming Phase - the tactical system need not be used again and the strategic system can take over. After the Priming Phase no human intervention will be necessary during the subsequent missions, which we will call the Automatic Phase. After each mission in the Automatic Phase, the analysts can perform the same job as before but on the strategic system. The analysts will decide whether or not to retrain the strategic system after each mission.

There could be several variations to this theme. For example, the tactical system could be tuned for minimal human interaction. During each mission in the Priming Phase, the operator may train the tactical system with only two or three speakers then allow the system to take over automatically. Every speaker the tactical system rejects as a target speaker can be trained automatically. In this way all speakers encountered during each mission will be trained by the tactical system. The onus will be on the analysts to consolidate the desired target speakers and their transmissions for training the strategic system.

To summarize, we believe we have the technology at hand to begin an operational speaker identification development program immediately. The

technology can support high performance speaker identification of at least 50 speakers in a wide range of channel conditions. The technology can support both tactical and strategic needs. The technology can also support real-time, on-line training and real-time identification during performance. We can also make improvements to this impressive list of capabilities during an initial prototype development program.

6.0 References

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Appendix 1

The LPC Cepstrum

Derivation of Linear Predictive Coefficients

Given a sampled signal $s(n)$, we want to estimate the signal at sample n from the weighted sum of a number of previous samples:

$$s(n) = \sum_{i=1}^{p} a(i)s(n-i) + e(n) \tag{1}$$

Where $e(n)$ denotes the error in the estimate. In vector notation, equation (1) becomes

$$\mathbf{s} = \mathbf{S}\mathbf{a} + \mathbf{e} \tag{2}$$

We want to find the *linear predictive coefficients* $\mathbf{a}$ such that the mean squared error is minimized. In other words we want to minimize

$$E = \|\mathbf{e}\|^2 = \mathbf{e} * \mathbf{e} \tag{3}$$

where * denotes the conjugate transpose.

The easiest way to find the coefficients $\mathbf{a}$ is by proving that the error is minimized when the coefficients $\mathbf{a}$ are orthogonal to the samples $\mathbf{S}$ (i.e., $\mathrm{E}\{s(n-i)e(n)\} = \mathbf{S} * \mathbf{e} = 0$, where $\mathrm{E}\{\bullet\}$ is the expectation operator).

Theorem

(a) The coefficients $\mathbf{a}$ that minimize E satisfy

$$\mathbf{S} * \mathbf{e} = \mathbf{S} * (\mathbf{s} - \mathbf{S}\mathbf{a}) = \mathbf{0} \tag{4}$$

(b) The resultant minimum is given by

$$\|\mathbf{e}_{\mathrm{min}}\|^2 = \mathbf{e} * \mathbf{s} \tag{5}$$

Proof Let $\mathbf{a}$ satisfy (4). Consider another set of weights $\mathbf{b}$, and let $\mathbf{f}$ be the new error, $\mathbf{s} - \mathbf{S}\mathbf{b}$. Therefore

$$\begin{aligned}\mathbf{f} &= \mathbf{s} - \mathbf{Sa} + \mathbf{Sa} - \mathbf{Sb} \\ &= \mathbf{e} + \mathbf{S}(\mathbf{a} - \mathbf{b})\end{aligned}$$

and

$$\begin{aligned}\|\mathbf{f}\|^2 &= \|\mathbf{e} + \mathbf{S}(\mathbf{a} - \mathbf{b})\|^2 \\ &= [\mathbf{e} + \mathbf{S}(\mathbf{a} - \mathbf{b})]^* [\mathbf{e} + \mathbf{S}(\mathbf{a} - \mathbf{b})] \\ &= \mathbf{e}^* \mathbf{e} + \mathbf{e}^* \mathbf{S}(\mathbf{a} - \mathbf{b}) + (\mathbf{a} - \mathbf{b})^* \mathbf{S}^* \mathbf{e} + [\mathbf{S}(\mathbf{a} - \mathbf{b})]^* [\mathbf{S}(\mathbf{a} - \mathbf{b})]\end{aligned}$$

The second and third terms are zero by (4). Thus

$$\begin{aligned}\|\mathbf{f}\|^2 &= \|\mathbf{e}\|^2 + \|\mathbf{S}(\mathbf{a} - \mathbf{b})\|^2 \\ &\geq \|\mathbf{e}\|^2\end{aligned}$$

with equality if $\mathbf{a} = \mathbf{b}$. This proves part (a). Now the error term is

$$\begin{aligned}\|\mathbf{e}\|^2 &= \mathbf{e}^* \mathbf{e} \\ &= \mathbf{e}^* (\mathbf{s} - \mathbf{Sa}) \\ &= \mathbf{e}^* \mathbf{s} - \mathbf{e}^* \mathbf{Sa}\end{aligned}$$

but by (4), $\mathbf{e}^* \mathbf{S} = \mathbf{0}$, which proves part (b).

Now we can proceed to the solution of the LPCs by using the preceding theorem as follows. First let us rewrite the error term from (1) as

$$e(n) = \sum_{i=0}^{p} a(i) s(n-i) \tag{6}$$

where $a(0) = 1$ and with the understanding that the rest of the coefficients have changed sign. Hence,

$$\begin{aligned}\mathrm{E}\{s(n-j)e(n)\} &= \sum_{n} s(n-j) \sum_{i=0}^{p} a(i) s(n-i) \\ &= \sum_{i=0}^{p} a(i) \sum_{n} s(n-i) s(n-j) = 0\end{aligned} \tag{7}$$

and from Equation (5) the minimum error is given by

$$\begin{aligned}\mathbf{e} * \mathbf{s} &= \mathrm{E}\{s(n)e(n)\} \\ &= \sum_n s(n)\sum_{i=0}^{p} a(i)s(n-i) \\ &= \sum_{i=0}^{p} a(i)\sum_n s(n-i)s(n) = E\end{aligned} \tag{8}$$

if we interchange the operations of averaging and summing. Now let r denote the autocorrelation function as

$$r_i = \sum_{n=i}^{N-1} s(n)s(n-i) \tag{9}$$

and Equations (7) and (8) become

$$\sum_{i=0}^{p} a(i)r_{i-j} = 0 \tag{10}$$

$$\sum_{i=0}^{p} a(i)r_i = E \tag{11}$$

The LPCs can be found directly from Equation (10) using Gaussian elimination; however, Levinson and Durbin (see [13]) found an iterative solution by using (10) in matrix notation and adding (11) as an auxiliary equation in the matrix. The resulting matrix becomes

$$\left[\begin{array}{ccccc} r_0 & r_1 & r_2 & \cdots & r_p \\ \hline r_1 & r_0 & r_1 & \cdots & r_{p-1} \\ r_2 & r_1 & r_0 & \cdots & r_{p-2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_p & r_{p-1} & r_{p-2} & \cdots & r_0 \end{array}\right] \left[\begin{array}{c} 1 \\ \hline a(1) \\ a(2) \\ \vdots \\ a(p) \end{array}\right] = \left[\begin{array}{c} E \\ \hline 0 \\ 0 \\ \vdots \\ 0 \end{array}\right] \tag{12}$$

There are only positive subscripts for r in (12) since for a real sequence s, $r_{-i} = r_i$. The trick to the iterative solution came from the observation that matrix $\mathbf{R}$ is both symmetric and Toeplitz.

Suppose we have solved (12) for $p = 1$. This means that we know $a_1(1)$ (the subscript denotes the iteration number) for which

$$\left[\begin{array}{cc} r_0 & r_1 \\ \hline r_1 & r_0 \end{array}\right]\left[\begin{array}{c} 1 \\ \hline a_1(1) \end{array}\right]=\left[\begin{array}{c} E_1 \\ \hline 0 \end{array}\right] \tag{13}$$

and we want to solve

$$\left[\begin{array}{ccc} r_0 & r_1 & r_2 \\ \hline r_1 & r_0 & r_1 \\ r_2 & r_1 & r_0 \end{array}\right]\left[\begin{array}{c} 1 \\ \hline a_2(1) \\ a_2(2) \end{array}\right]=\left[\begin{array}{c} E_2 \\ \hline 0 \\ 0 \end{array}\right] \tag{14}$$

Since $\mathbf{R}$ is Toeplitz and symmetric, equation (14) can be solved if the vectors were reversed as

$$\left[\begin{array}{cc} r_0 & r_1 \\ \hline r_1 & r0 \end{array}\right]\left[\begin{array}{c} a_1(1) \\ \hline 1 \end{array}\right]=\left[\begin{array}{c} 0 \\ \hline E_1 \end{array}\right] \tag{15}$$

We can solve (14) by making the following substitution:

$$\begin{bmatrix} 1 \\ a_2(1) \\ a_2(2) \end{bmatrix}=\begin{bmatrix} 1 \\ a_1(1) \\ 0 \end{bmatrix}+k_2\begin{bmatrix} 0 \\ a_1(1) \\ 1 \end{bmatrix} \tag{16}$$

where k_2 is some constant. Thus

$$\left[\begin{array}{ccc} r_0 & r_1 & r_2 \\ \hline r_1 & r_0 & r_1 \\ r_2 & r_1 & r_0 \end{array}\right]\left\{\begin{bmatrix} 1 \\ a_1(1) \\ 0 \end{bmatrix}+k_2\begin{bmatrix} 0 \\ a_1(1) \\ 1 \end{bmatrix}\right\}=\left[\begin{array}{c} E_1 \\ \hline 0 \\ q \end{array}\right]+k_2\left[\begin{array}{c} q \\ \hline 0 \\ E_1 \end{array}\right] \tag{17}$$

where q is another term. Equation (17) can have a solution only if the right hand side is all zeros under the partition. We can accomplish this by forcing k_2 to satisfy

$$q+k_2E_1=0$$

Therefore, we find that the solution to (14) is (16) where

$$
\begin{aligned}
k_2 &= -\frac{q}{E_1} \\
&= -\frac{1}{E_1}\sum_{i=0}^{1} a(i) r_{2-i}
\end{aligned} \tag{18}
$$

From (14) and (17) we find our new predictor error to be

$$E_2 = E_1(1-k_2^2) \tag{19}$$

We can finally generalize Equations (16), (18), and (19) for the nth iteration and state the solution in the following iterative form:

1. For $n = 0$, $E_0 = r_0$

2. For $n \geq 1$

a) $$k_n = \frac{-1}{E_{n-1}}\sum_{i=0}^{n-1} a_{n-1}(i) r_{n-i}$$

b) $$a_n(n) = k_n$$

c) For $i = 1$ to $n-1$

$$a_n(i) = a_{n-1}(i) + k_n a_{n-1}(n-i)$$

d) $$E_n = E_{n-1}(1-k_n^2)$$

This algorithm is know as the autocorrelation or Levinson and Durbin method and was restated from [13]. There are other methods of finding the LPCs, each with their strengths and weakness. The autocorrelation method is the most popular in speech processing.

Derivation of Cepstral Coefficients from LPCs

The all-pole model of the vocal tract is defined as (see [6],[7], or [13])

$$H(z) = \frac{E}{A(z)} \tag{20}$$

where $H(z)$ and $A(z)$ are the Z transforms of the impulse response $h(n)$ of the vocal tract filter and predictor coefficients $a(n)$ respectively. By definition, the cepstrum of $h(n)$ is

$$C(z) \equiv \log H(z) \tag{21}$$

or

$$\begin{aligned} C(z) &= \log\left(\frac{E}{A(z)}\right) \\ &= \log E - \log A(z) \end{aligned} \tag{22}$$

Now take the derivative of both sides of (22) and multiply each side by z,

$$\frac{z\,dC(z)}{dz} = -\frac{z\,dA(z)}{dz}\frac{1}{A(z)} \tag{23}$$

multiply by $A(z)$,

$$\frac{z\,dC(z)\,A(z)}{dz} = -\frac{z\,dA(z)}{dz} \tag{24}$$

and find the inverse Z transform

$$-nc(n) * a(n) = na(n) \tag{25}$$

We now expand the convolution on the left side and regroup some terms.

$$-\sum_{k=0}^{p}(n-k)c(n-k)a(k) = na(n)$$

$$-nc(n) - \sum_{k=1}^{p}(n-k)c(n-k)a(k) = na(n)$$

$$c(n) = -a(n) - \sum_{k=1}^{p}\frac{n-k}{n}c(n-k)a(k)$$

From (21), for $n=0$, $c(0)=\log E$ and since $c(m)=0$ for $m<0$ the final form of the iterative equation for $n>0$ becomes

$$c(n) = -a(n) - \sum_{k=1}^{n-1} \frac{n-k}{n} c(n-k)a(k) \tag{26}$$

The Delta Cepstrum

The derivative of each cepstral coefficient at frame n is approximated using an N point linear regression as follows:

$$r = \frac{N-1}{2}, \quad N \text{ is odd} \tag{27}$$

$$R = \sum_{i=-r}^{r} i^2 \tag{28}$$

$$\Delta C_i(n) = \sum_{m=-r}^{r} \frac{mC_i(n-m)}{R} \tag{29}$$

The Hamming Window Lifter

To lifter the cepstrum $c(n)$ of some frame of speech, perform a point-by-point multiplication $c(n)$ with a lifter, or *window* $w(n)$. We obtained the best performance from the Hamming window, which is defined as

$$w(n) = \begin{cases} 0.54 - 0.46\cos\left(\dfrac{2\pi n}{N-1}\right), & \text{for } |n| \le N \\ 0, & \text{otherwise} \end{cases} \tag{30}$$

Appendix 2

Perceptual Linear Prediction

PLP Model and Equations

The PLP algorithm is an auditory-like model of the auditory periphery that encompasses some psychophysical concepts of hearing such as logarithmically scaled critical band filters, equal loudness preemphasis, and the intensity-loudness power law. In general, the PLP technique incorporates these three concepts within the well known and efficient linear predictive all-pole model of speech. A full discussion of the PLP process and its theoretical underpinnings are found in [1].

The PLP process begins by finding the spectrum of each speech frame by using the FFT. More precisely, given a windowed sampled speech signal frame $s(n)$,

$$S(k) = \sum_{n=0}^{N-1} s(n) e^{-j\frac{2\pi}{N}kn} \quad k = 0,1,\ldots,N-1 \tag{1}$$

$$P(k) = |S(k)|^2 \tag{2}$$

where N is the number of points in the frame $s(n)$. From Equation (1), we know the frequency resolution f_0 of S by

$$f_0 = \frac{F_s}{N} \tag{3}$$

where F_s is the sampling frequency.

Bark scaled critical-band filter banks are then computed from the spectrum and the critical-band filters. In general, the uniformly scaled frequency axis f of the spectrum is warped into the logarithmically scaled Bark frequency axis ξ by

$$\xi(f) = 6\ln\left\{f/600 + \left[(f/600)^2 + 1\right]^{0.5}\right\}. \tag{4}$$

The warped spectrum is then convolved with the critical band filter. Hermansky developed the following piece-wise implementation of the filter

$$X(\xi) = \begin{cases} 0 & \text{for } \xi < -1.3, \\ 10^{2.5(\xi+0.5)} & \text{for } -1.3 \le \xi \le -0.5, \\ 1 & \text{for } -0.5 < \xi < 0.5, \\ 10^{-1.0(\xi-0.5)} & \text{for } 0.5 \le \xi \le 2.5, \\ 0 & \text{for } \xi > 2.5. \end{cases} \tag{5}$$

A more practical approach used by Hermansky is to design Bark scaled filter bank functions in the uniform frequency f domain based on Equation (5) and the inverse of Equation (4), which is

$$f = 600 \sinh(\xi / 6). \tag{6}$$

This is done by determining the number of filters required to cover the entire bandwidth of the signal in approximate unit Bark intervals. The bandwidth of the signal in Bark is found by inserting the bandwidth of the signal in Hz in Equation (4). For this investigation, we used 8 KHz sampled speech signals; thus, the bandwidth in Bark is approximately 15.58. A total of 17 filters were chosen, spaced at 0.9734 Bark. Now that the ends points, in Bark, of each filter is known, the end points in Hz can be computed using Equation (6). The closest frequency index integers k are then determined for each filter endpoint. The actual weights of each filter can now be computed by iterating k through the limits of each filter, finding the associated frequency f in Hz of each k, computing the associated Bark frequency ξ, and finally finding the appropriate weight value of the filter at that point in frequency by using Equation (5). One must realize that the reflection of Equation (5) is actually used since $X(\xi)$ is convolved with the warped spectrum $S(\xi)$ or

$$\Delta(\lambda) = \sum_{\xi} P(\xi) X(\lambda - \xi). \tag{7}$$

To incorporate equal-loudness weighing of the spectrum, the critical-band filters are preemphasized using the following equation

$$E(f) = \left[\left(f^2 + 1200^2\right) f^4\right] \Big/ \left[\left(f^2 + 400^2\right)^2 \left(f^2 + 3100^2\right)\right]. \tag{8}$$

Once the critical band filters are computed, the Bark filter bank representation of the signal can be found by

$$\Delta(i) = \sum_{k=k_{il}}^{k_{ih}} w_i(k) P(k) \quad i = 1,2,\ldots,I \tag{9}$$

where I is the number of filter banks, k_{il} is the lowest frequency index of the ith filter, and k_{ih} is the high frequency index of the ith filter.

The last operation in the auditory-like process is to compress the Bark filter bank spectrum with the intensity-loudness power law. Hermansky suggested a cubic-root compression, producing

$$\mathrm{B}(i) = \Delta(i)^{0.33} \quad i = 1,2,\ldots,I. \tag{10}$$

At this stage in the PLP process, the all-pole model of the signal can be computed. We know that the autocorrelation function $R(n)$ of $s(n)$ can be found by

$$\begin{aligned} R(n) &= \Im^{-1}\left\{S(k)S(k)^{*}\right\} \\ &= \Im^{-1}\left\{|S(k)|^{2}\right\} \\ &= \Im^{-1}\left\{P(k)\right\} \end{aligned} \tag{11}$$

where $\Im^{-1}$ is the inverse FFT. Therefore, autocorrelation-like parameters can be obtained from the inverse FFT of $\mathrm{B}(i)$, which was derived from $P(k)$. Since we want real valued autocorrelation-like coefficients, the cosine transform is used instead of the FFT; thus

$$\hat{R}(j) = \sum_{i=1}^{I} \mathrm{B}(i)\cos[\pi i j/I] \quad j = 1,2,\ldots,J \tag{12}$$

where J is the order of the all-pole or linear predictive model. The $\hat{R}(j)$ can now be used in the autocorrelation method for finding the linear predictive coefficients (LPCs) (see Appendix 1).

Appendix 3

RASTA Filtering

The RASTA Filter Equations

Hermansky [1] developed a simple technique for reducing channel induced distortions in speech. He called the procedure the RelAtive SpecTrAl (RASTA) methodology. The RASTA procedure bandpass filters each critical band filter bank spectral channel B(i) through a filter with the following system function

$$H(z) = \frac{0.1(2.0 + 1.0z^{-1} - 1.0z^{-3} - 2.0z^{-4})}{z^{-4}(1-.98z^{-1})} \tag{1}$$

prior to the all-pole modeling step. In other words, the ith filtered channel at frame n, $\hat{B}(i,n)$, is found by

$$\hat{B}(i,n) = \begin{cases} 0.2B(i,n) + 0.1B(i,n-1) - 0.1B(i,n-3) - 0.2B(i,n-4) + 0.98\hat{B}(i,n-1), & \text{for } n \geq 4 \\ 0, & \text{for } n < 4 \end{cases} \tag{2}$$

The LPC cepstrum can also be filtered in the same way.

Appendix 4

LBG Vector Quantization

Codebook Training

The Linde-Buzo-Gray (LBG) algorithm clusters an N dimensional training data set into K codewords, or centroids, in N dimensional space, such that all vectors in the training set can be *quantized* with minimum distortion. We use the mean squared error (MSE) distortion measure in this research. The number of clusters K is chosen by the user. The LBG algorithm begins by initializing one codeword to the centroid of all input vectors . On each iteration of the algorithm, each existing codeword is split in two by taking + or - 1% of each codeword's element. After the codebook is doubled in this manner, the codebook centroids are adjusted using the LBG iteration. This process continues until the desired size of the codebook is generated. If $K \neq 2^m$, for some m then a point will be reached when doubling the codebook will make it too large. At this point individual codewords must be chosen for splitting. Two possible criteria are used for splitting: a density criteria (the codeword that decodes the largest number of training vectors is split) and a largest average MSE criteria (the codeword that produces the largest average MSE over its set of training vectors is split).

LBG Iteration

A) Initialize Codebook: As described above

B) Iteration:

1. For each training vector $\mathbf{x}$, quantize $\mathbf{x}$ into the codeword $\bar{\mathbf{x}}_{k*}$ such that

$$k* = \arg\min_k \|x - \bar{x}_k\|^2$$

2. Compute the total average distortion D produced by each vector $\mathbf{x}$ and the new codebook.

$$D = \sum_{i-1}^{L} \left\| \mathbf{x}_i - Q(\mathbf{x}_i) \right\|^2$$

where L is the number of training vectors and $Q(\mathbf{x}_i)$ is the codeword that vector $\mathbf{x}_i$ was assigned to in steps 1. If D has changed less than some small amount *stop*.

3. Find new centroid of each codeword and go to step 1.

Appendix 5

Classification Based on Score Statistics

In section 3.4, we found that a candidate speaker is chosen when a test transmission produces the lowest average mean squared error score against that speaker's codebook. We can also use the score statistics of the speakers for our decision making process. For example, we can compare a speaker's test score against the scores that speaker's codebook has produced in the past. In this way we can make a decision based on the speaker's score relative to the scores his codebook has produced for his speech as well as everyone else's speech in the target group. In other words, we want to find the probability that a test transmission was generated by speaker j given speaker j's current score is less than what his codebook has previously generated. The speaker that produces the largest probability is considered the candidate speaker.

More specifically, for a set of target speakers C, choose speaker k as candidate if

$$k \ni P\left(S_k \middle| E_k > e_k\right) = \max P\left(S_j \middle| E_j > e_j\right) \forall j \in C \tag{1}$$

where S_j denotes the jth speaker, e_j is S_j's classifier output score, and E_j is the set of scores previously produced by S_j. To find the desired probability we use Bayes' rule:

$$P\left(S_j \middle| E_j > e_j\right) = \frac{P\left(E_j > e_j \middle| S_j\right) P\left(S_j\right)}{P\left(E_j > e_j\right)} \tag{2}$$

We can find each term on the right hand side of (2) in a straightforward manner. We know that the cumulative distribution function of some random variable X is defined as

$$F_X(x) \equiv P(X \leq x) \tag{3}$$

and

$$P(X > x) = 1 - P(X \leq x) \tag{4}$$

Therefore, $P(E_j > e_j | S_j)$ is one minus the cumulative distribution of scores produced by encoding speaker j's previous transmissions - usually the training transmissions - through speaker j's codebook. Similarly, $P(E_j > e_j)$ is one minus the cumulative distribution of scores produced by encoding the training transmissions of *all* speakers through speaker j's codebook. The probability of encountering speaker j, $P(S_j)$, is easily found by dividing speaker j's training signal length by the sum of the training signal lengths of all speakers in the target set.

If all speakers are regarded as equally likely, then $P(E_j > e_j)$ must be normalized to account for equally probable speakers. Equation (1) becomes:

$$P(S_j | E_j > e_j) = \frac{P(E_j > e_j | S_j)}{\overline{P}(E_j > e_j)} \tag{4}$$

where $\overline{P}(E_j > e_j)$ is the appropriately normalized $P(E_j > e_j)$.

Appendix 6

Out-of-Set Detection

Definitions

$C = \{S_1, S_2, \cdots, S_K\}$ - Set of K trained speakers

$Q_k = \{q_{k1}, q_{k2}, \cdots, q_{kN}\}, \quad k = 1,2,\cdots,K$ - Speaker k's codebook of N codewords

$\Theta = \{\theta_1, \theta_2, \cdots, \theta_M\}$ - Test signal made up of M vectors

$\Phi_k = \{\phi_{k1}, \phi_{k2}, \cdots, \phi_{kL}\}, \quad k = 1,2,\cdots,K$ - Speaker k's training signal

$d(\Theta, Q_k) = \frac{1}{M}\sum_{i=1}^{M} \min\|\theta_i - q_{kj}\|, \quad j = 1,2,\cdots,N$ - Speaker k's codebook output score

$e_j = \min d(\Theta, Q_k), \quad k = 1,2,\cdots,K$ - Candidate speaker j's score

Global MSE Score Threshold

Given global threshold T and candidate speaker S_j's output score e_j, if $e_j > T$ then reject S_j as target speaker, otherwise accept S_j as target speaker.

N Closest Speakers' Scores Threshold

For each speaker j test all other speakers training signals against speaker j's codebook and rank the resulting scores. In other words find

$$d_i(\Phi_k, Q_j), k \neq j, i = 1,2,\cdots K \tag{1}$$

where $d_1(\bullet)$ is the lowest score and $d_K(\bullet)$ is the highest score. Now find the following threshold:

$$T_j = \frac{1}{N}\sum_{l=1}^{N} d_l(\Phi_k, Q_j) \tag{2}$$

where N is predetermined by the user. If $e_j > T_j$ then reject S_j as target speaker, otherwise accept S_j as target speaker.

Cohort Normalized Scores Thresholds

Find S_j *cohorts* by testing speaker j's training signal against all other speakers codebooks and rank the resulting scores in a similar fashion as in (1):

$$d_i\left(\Phi_j, Q_k\right), k \neq j, i = 1,2,\cdots K \tag{3}$$

The N cohorts are the speakers that produced N lowest scores. We will call speaker j's cohorts group J. Now average the cohorts' scores:

$$\bar{d}\left(\Phi_j, Q_J\right) = \frac{1}{N}\sum_{i=1}^{N} d_i\left(\Phi_j, Q_k\right), \quad \ni S_k \in J \tag{4}$$

Finally, upon testing $_j$if

$$\alpha_j \leq \frac{e_j - \bar{d}\left(\Theta, Q_J\right)}{d\left(\Phi_j, Q_j\right) - \bar{d}\left(\Phi_j, Q_J\right)} \leq \beta_j \tag{5}$$

then accept S_j as target speaker, otherwise reject S_j.

Probabilistic Thresholds

Refer to Appendix 5 for definitions. If $P\left(E_j > e_j \middle| S_j\right) < T_j$ then rejects S_j as target speaker, otherwise accept S_j.

Appendix 7

Results Print Outs

KING Database Results

This is the MSE ratios of 14th order:
1) liftered cepstrum24
2) delta cepstrum (7 point linear regression)
3) acceleration cepstrum (7 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 2, 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.01	1.15	1.11	1.13	1.21	1.09	1.20	1.08	1.09	1.09	1.16	1.06	1.14	1.14	1.14	1.14	1.13	1.04	1.07	1.08	1.03	1.12	1.08	1.06	1.13	1.13
2	1.11	1.00	1.14	1.15	1.23	1.14	1.20	1.08	1.17	1.11	1.10	1.11	1.12	1.12	1.05	1.16	1.13	1.12	1.14	1.09	1.11	1.15	1.14	1.11	1.14	1.15
3	1.12	1.22	1.00	1.13	1.20	1.09	1.16	1.13	1.14	1.11	1.08	1.13	1.15	1.19	1.21	1.13	1.14	1.14	1.13	1.12	1.13	1.11	1.10	1.17	1.09	1.09
4	1.13	1.25	1.18	1.00	1.30	1.13	1.16	1.11	1.18	1.22	1.13	1.14	1.13	1.16	1.22	1.23	1.19	1.17	1.15	1.17	1.13	1.06	1.18	1.18	1.12	1.14
5	1.16	1.34	1.10	1.22	1.00	1.08	1.16	1.23	1.25	1.17	1.20	1.07	1.29	1.18	1.28	1.21	1.22	1.11	1.15	1.17	1.16	1.18	1.11	1.16	1.13	1.13
6	1.13	1.19	1.08	1.17	1.08	1.00	1.13	1.11	1.17	1.09	1.10	1.00	1.16	1.09	1.15	1.17	1.13	1.06	1.08	1.12	1.06	1.12	1.09	1.11	1.11	1.12
7	1.10	1.27	1.05	1.16	1.16	1.08	1.00	1.11	1.16	1.16	1.11	1.10	1.16	1.15	1.22	1.17	1.18	1.14	1.13	1.18	1.10	1.08	1.08	1.14	1.08	1.09
8	1.07	1.11	1.11	1.14	1.23	1.11	1.11	1.00	1.08	1.12	1.08	1.08	1.04	1.10	1.11	1.12	1.09	1.09	1.09	1.07	1.06	1.03	1.08	1.08	1.11	1.15
9	1.04	1.14	1.08	1.18	1.21	1.11	1.21	1.08	1.00	1.06	1.16	1.15	1.11	1.13	1.14	1.12	1.07	1.06	1.03	1.04	1.05	1.10	1.06	1.02	1.13	1.12
10	1.07	1.14	1.05	1.12	1.15	1.08	1.14	1.11	1.08	1.00	1.12	1.09	1.09	1.10	1.12	1.09	1.11	1.05	1.05	1.03	1.04	1.09	1.03	1.03	1.11	1.12
11	1.14	1.22	1.06	1.13	1.17	1.10	1.14	1.11	1.14	1.16	1.00	1.10	1.15	1.13	1.18	1.15	1.19	1.12	1.12	1.14	1.14	1.08	1.08	1.15	1.04	1.05
12	1.12	1.17	1.14	1.17	1.19	1.11	1.17	1.12	1.21	1.13	1.09	1.00	1.15	1.09	1.12	1.25	1.20	1.10	1.19	1.15	1.10	1.13	1.15	1.14	1.12	1.16
13	1.16	1.17	1.11	1.18	1.33	1.15	1.19	1.10	1.10	1.16	1.12	1.16	1.00	1.20	1.16	1.13	1.18	1.18	1.15	1.14	1.14	1.05	1.15	1.16	1.17	1.14
14	1.10	1.19	1.07	1.09	1.10	1.08	1.09	1.06	1.16	1.11	1.06	1.06	1.14	1.00	1.10	1.17	1.11	1.07	1.08	1.06	1.09	1.06	1.04	1.06	1.05	1.10
15	1.12	1.14	1.19	1.20	1.32	1.20	1.27	1.12	1.24	1.12	1.15	1.14	1.18	1.09	1.00	1.25	1.22	1.16	1.19	1.14	1.11	1.19	1.15	1.13	1.20	1.22
16	1.12	1.19	1.11	1.09	1.30	1.12	1.15	1.11	1.05	1.12	1.08	1.14	1.06	1.18	1.18	1.01	1.10	1.18	1.09	1.09	1.12	1.07	1.13	1.12	1.13	1.14
17	1.06	1.14	1.06	1.11	1.13	1.03	1.10	1.07	1.04	1.03	1.10	1.04	1.10	1.06	1.14	1.04	1.01	1.09	1.04	1.05	1.05	1.05	1.05	1.03	1.10	1.08
18	1.05	1.12	1.12	1.20	1.21	1.11	1.19	1.08	1.14	1.06	1.12	1.04	1.12	1.10	1.08	1.19	1.14	1.00	1.09	1.05	1.02	1.08	1.07	1.07	1.16	1.16
19	1.10	1.21	1.07	1.15	1.13	1.06	1.22	1.12	1.08	1.14	1.15	1.13	1.17	1.18	1.25	1.11	1.11	1.10	1.00	1.07	1.12	1.13	1.05	1.13	1.11	1.12
20	1.09	1.18	1.12	1.21	1.19	1.15	1.22	1.10	1.13	1.08	1.17	1.13	1.19	1.17	1.18	1.22	1.15	1.07	1.06	1.00	1.07	1.14	1.09	1.04	1.13	1.17
21	1.16	1.23	1.14	1.30	1.28	1.17	1.25	1.19	1.16	1.16	1.22	1.13	1.23	1.20	1.18	1.23	1.19	1.12	1.18	1.16	1.00	1.16	1.17	1.14	1.22	1.22
22	1.10	1.24	1.06	1.08	1.22	1.10	1.13	1.08	1.11	1.13	1.09	1.12	1.09	1.16	1.20	1.13	1.15	1.13	1.12	1.11	1.10	1.00	1.08	1.15	1.09	1.12
23	1.11	1.22	1.09	1.13	1.08	1.07	1.13	1.07	1.15	1.11	1.09	1.06	1.16	1.11	1.18	1.22	1.16	1.07	1.05	1.07	1.08	1.05	1.00	1.09	1.05	1.11
24	1.06	1.21	1.10	1.11	1.16	1.10	1.16	1.08	1.07	1.07	1.12	1.10	1.15	1.05	1.11	1.15	1.10	1.08	1.04	1.03	1.07	1.07	1.04	1.00	1.11	1.14
25	1.15	1.27	1.05	1.14	1.17	1.11	1.15	1.12	1.17	1.18	1.07	1.13	1.19	1.14	1.23	1.17	1.18	1.15	1.13	1.13	1.16	1.11	1.07	1.16	1.00	1.07
26	1.12	1.23	1.05	1.14	1.16	1.07	1.09	1.09	1.18	1.14	1.07	1.07	1.13	1.12	1.19	1.19	1.17	1.08	1.13	1.14	1.13	1.08	1.08	1.17	1.05	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Number wrong: 0   Percent Correct: 100.000

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (5 point linear regression)
3) acceleration cepstrum (5 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 2, 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.01	1.14	1.10	1.12	1.21	1.08	1.19	1.08	1.08	1.08	1.16	1.05	1.14	1.13	1.13	1.12	1.11	1.03	1.06	1.07	1.01	1.10	1.07	1.06	1.13	1.12
2	1.10	1.00	1.14	1.14	1.23	1.13	1.18	1.08	1.16	1.10	1.10	1.10	1.12	1.11	1.05	1.14	1.12	1.12	1.13	1.09	1.09	1.14	1.13	1.11	1.14	1.15
3	1.12	1.20	1.00	1.12	1.19	1.10	1.16	1.12	1.14	1.10	1.08	1.12	1.14	1.17	1.20	1.12	1.14	1.13	1.13	1.13	1.11	1.11	1.09	1.18	1.09	1.08
4	1.14	1.24	1.18	1.00	1.29	1.14	1.15	1.12	1.18	1.21	1.13	1.13	1.15	1.15	1.21	1.21	1.17	1.17	1.15	1.17	1.12	1.07	1.16	1.17	1.12	1.12
5	1.16	1.32	1.10	1.21	1.00	1.08	1.16	1.21	1.24	1.16	1.18	1.07	1.29	1.16	1.27	1.20	1.19	1.11	1.15	1.17	1.15	1.17	1.12	1.14	1.13	1.12
6	1.13	1.17	1.09	1.16	1.09	1.00	1.14	1.10	1.16	1.10	1.10	1.01	1.17	1.08	1.14	1.16	1.13	1.06	1.08	1.12	1.06	1.13	1.09	1.10	1.11	1.11
7	1.10	1.24	1.05	1.14	1.16	1.07	1.00	1.09	1.14	1.15	1.10	1.09	1.15	1.13	1.19	1.15	1.15	1.12	1.12	1.17	1.09	1.05	1.07	1.12	1.07	1.07
8	1.06	1.09	1.09	1.13	1.22	1.10	1.10	1.00	1.06	1.11	1.08	1.07	1.05	1.10	1.09	1.10	1.07	1.08	1.07	1.07	1.05	1.03	1.07	1.08	1.11	1.13
9	1.05	1.14	1.07	1.17	1.21	1.09	1.19	1.08	1.00	1.06	1.15	1.12	1.12	1.11	1.13	1.11	1.07	1.06	1.02	1.03	1.04	1.10	1.06	1.01	1.12	1.10
10	1.06	1.13	1.04	1.10	1.14	1.07	1.12	1.10	1.08	1.00	1.11	1.07	1.09	1.08	1.10	1.07	1.10	1.04	1.04	1.03	1.02	1.07	1.03	1.03	1.11	1.10
11	1.13	1.20	1.06	1.11	1.17	1.10	1.14	1.10	1.13	1.16	1.00	1.10	1.15	1.12	1.16	1.14	1.17	1.13	1.11	1.13	1.14	1.07	1.08	1.14	1.03	1.04
12	1.13	1.16	1.14	1.16	1.18	1.11	1.18	1.12	1.21	1.15	1.10	1.00	1.16	1.09	1.12	1.24	1.19	1.11	1.18	1.16	1.09	1.13	1.15	1.14	1.12	1.15
13	1.14	1.15	1.12	1.16	1.33	1.15	1.17	1.11	1.09	1.14	1.12	1.15	1.00	1.19	1.14	1.12	1.16	1.17	1.13	1.13	1.13	1.05	1.14	1.15	1.17	1.13
14	1.11	1.18	1.08	1.09	1.10	1.09	1.10	1.06	1.16	1.11	1.07	1.06	1.15	1.00	1.10	1.16	1.11	1.07	1.08	1.06	1.09	1.07	1.05	1.06	1.06	1.10
15	1.10	1.12	1.18	1.19	1.30	1.19	1.25	1.10	1.23	1.11	1.15	1.12	1.18	1.08	1.00	1.23	1.19	1.14	1.16	1.13	1.10	1.19	1.14	1.12	1.19	1.20
16	1.11	1.17	1.11	1.09	1.30	1.11	1.13	1.10	1.04	1.12	1.08	1.13	1.06	1.15	1.16	1.00	1.09	1.17	1.08	1.09	1.11	1.06	1.14	1.11	1.12	1.13
17	1.06	1.14	1.07	1.12	1.15	1.03	1.11	1.09	1.05	1.05	1.11	1.05	1.12	1.07	1.13	1.04	1.00	1.09	1.05	1.05	1.05	1.07	1.05	1.04	1.11	1.08
18	1.06	1.11	1.11	1.19	1.21	1.11	1.19	1.08	1.14	1.06	1.13	1.03	1.13	1.10	1.07	1.18	1.14	1.00	1.08	1.06	1.01	1.09	1.07	1.07	1.16	1.14
19	1.09	1.19	1.06	1.13	1.13	1.05	1.19	1.10	1.08	1.13	1.13	1.10	1.16	1.16	1.22	1.09	1.10	1.09	1.00	1.06	1.09	1.11	1.05	1.11	1.10	1.10
20	1.09	1.16	1.11	1.19	1.20	1.14	1.21	1.10	1.13	1.09	1.17	1.11	1.20	1.17	1.16	1.21	1.14	1.07	1.05	1.00	1.06	1.14	1.10	1.04	1.13	1.15
21	1.15	1.22	1.13	1.27	1.27	1.15	1.23	1.17	1.16	1.15	1.21	1.11	1.23	1.18	1.16	1.21	1.18	1.11	1.17	1.16	1.00	1.15	1.16	1.14	1.21	1.19
22	1.11	1.22	1.06	1.09	1.23	1.11	1.13	1.09	1.10	1.12	1.10	1.13	1.11	1.14	1.19	1.13	1.15	1.13	1.13	1.11	1.11	1.00	1.09	1.15	1.10	1.11
23	1.10	1.20	1.09	1.12	1.08	1.07	1.12	1.07	1.14	1.10	1.09	1.04	1.17	1.08	1.16	1.20	1.14	1.07	1.04	1.07	1.07	1.04	1.00	1.08	1.06	1.09
24	1.06	1.20	1.11	1.11	1.18	1.10	1.17	1.09	1.08	1.08	1.12	1.10	1.16	1.06	1.11	1.15	1.09	1.09	1.05	1.04	1.08	1.09	1.06	1.00	1.11	1.13
25	1.14	1.23	1.04	1.13	1.15	1.11	1.14	1.10	1.16	1.17	1.06	1.12	1.18	1.12	1.21	1.16	1.16	1.14	1.12	1.12	1.15	1.09	1.07	1.15	1.00	1.05
26	1.12	1.21	1.06	1.13	1.17	1.09	1.09	1.09	1.17	1.14	1.07	1.07	1.14	1.11	1.19	1.19	1.16	1.09	1.13	1.14	1.12	1.08	1.09	1.17	1.06	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Number wrong: 0 Percent Correct: 100.000

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (7 point linear regression)
3) acceleration cepstrum (7 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 3, 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.01	1.12	1.11	1.13	1.20	1.09	1.18	1.07	1.08	1.08	1.15	1.06	1.13	1.13	1.13	1.12	1.13	1.04	1.06	1.05	1.02	1.10	1.08	1.05	1.13	1.12
2	1.11	1.00	1.15	1.16	1.22	1.15	1.18	1.09	1.16	1.12	1.11	1.11	1.13	1.12	1.06	1.15	1.14	1.12	1.14	1.10	1.11	1.14	1.14	1.12	1.15	1.15
3	1.13	1.20	1.00	1.12	1.18	1.10	1.15	1.12	1.13	1.10	1.09	1.12	1.13	1.16	1.20	1.12	1.15	1.14	1.13	1.12	1.11	1.10	1.09	1.17	1.08	1.07
4	1.13	1.23	1.20	1.00	1.29	1.14	1.15	1.11	1.18	1.21	1.12	1.14	1.16	1.16	1.20	1.20	1.20	1.18	1.15	1.17	1.14	1.06	1.17	1.16	1.12	1.13
5	1.15	1.29	1.09	1.19	1.00	1.06	1.15	1.19	1.21	1.16	1.18	1.07	1.27	1.15	1.26	1.18	1.19	1.10	1.13	1.14	1.14	1.16	1.10	1.13	1.13	1.11
6	1.12	1.16	1.09	1.17	1.08	1.00	1.12	1.11	1.15	1.10	1.09	1.01	1.17	1.08	1.15	1.16	1.13	1.06	1.08	1.11	1.06	1.13	1.09	1.10	1.11	1.12
7	1.10	1.23	1.07	1.16	1.16	1.08	1.00	1.09	1.16	1.15	1.09	1.11	1.15	1.14	1.20	1.14	1.17	1.13	1.12	1.16	1.10	1.06	1.07	1.12	1.07	1.08
8	1.06	1.08	1.10	1.12	1.19	1.09	1.08	1.00	1.06	1.10	1.06	1.07	1.03	1.08	1.08	1.09	1.07	1.07	1.08	1.06	1.05	1.02	1.07	1.07	1.10	1.11
9	1.04	1.13	1.08	1.16	1.19	1.09	1.19	1.07	1.01	1.05	1.15	1.12	1.11	1.11	1.13	1.10	1.08	1.06	1.02	1.03	1.04	1.08	1.06	1.00	1.10	1.08
10	1.06	1.12	1.04	1.10	1.13	1.05	1.11	1.09	1.06	1.00	1.10	1.07	1.08	1.08	1.11	1.06	1.11	1.04	1.04	1.03	1.02	1.07	1.03	1.03	1.10	1.10
11	1.15	1.20	1.08	1.13	1.17	1.11	1.14	1.11	1.14	1.18	1.00	1.12	1.15	1.13	1.18	1.14	1.19	1.15	1.12	1.14	1.14	1.09	1.10	1.15	1.05	1.06
12	1.12	1.14	1.14	1.17	1.17	1.11	1.17	1.12	1.18	1.14	1.10	1.00	1.15	1.07	1.12	1.22	1.18	1.10	1.17	1.15	1.09	1.12	1.15	1.13	1.12	1.15
13	1.13	1.16	1.12	1.16	1.30	1.14	1.16	1.10	1.09	1.14	1.11	1.15	1.00	1.18	1.15	1.12	1.17	1.17	1.13	1.13	1.13	1.06	1.14	1.15	1.16	1.12
14	1.10	1.15	1.07	1.10	1.09	1.08	1.10	1.05	1.13	1.09	1.06	1.06	1.14	1.00	1.08	1.14	1.09	1.07	1.06	1.05	1.08	1.07	1.04	1.05	1.06	1.09
15	1.09	1.09	1.16	1.17	1.25	1.16	1.21	1.09	1.21	1.08	1.11	1.10	1.17	1.06	1.00	1.19	1.18	1.11	1.13	1.09	1.09	1.16	1.11	1.10	1.16	1.17
16	1.12	1.19	1.12	1.09	1.30	1.13	1.13	1.10	1.05	1.13	1.09	1.14	1.07	1.16	1.18	1.00	1.11	1.19	1.09	1.09	1.13	1.05	1.15	1.14	1.12	1.13
17	1.06	1.13	1.07	1.11	1.14	1.04	1.10	1.07	1.05	1.04	1.10	1.06	1.12	1.07	1.14	1.04	1.01	1.09	1.04	1.05	1.06	1.07	1.05	1.03	1.10	1.08
18	1.06	1.11	1.12	1.20	1.20	1.10	1.18	1.08	1.13	1.07	1.13	1.02	1.13	1.09	1.08	1.18	1.15	1.01	1.08	1.06	1.01	1.08	1.08	1.08	1.14	1.14
19	1.09	1.17	1.06	1.13	1.12	1.04	1.19	1.09	1.07	1.12	1.12	1.10	1.15	1.15	1.21	1.08	1.10	1.08	1.00	1.06	1.09	1.11	1.05	1.10	1.10	1.09
20	1.09	1.15	1.11	1.19	1.18	1.13	1.22	1.09	1.12	1.09	1.16	1.10	1.19	1.16	1.15	1.19	1.15	1.07	1.05	1.00	1.06	1.13	1.09	1.03	1.11	1.13
21	1.15	1.21	1.14	1.26	1.26	1.15	1.22	1.17	1.15	1.16	1.20	1.10	1.21	1.17	1.17	1.21	1.20	1.11	1.16	1.15	1.00	1.15	1.16	1.15	1.19	1.19
22	1.11	1.23	1.07	1.08	1.22	1.10	1.13	1.08	1.11	1.13	1.09	1.14	1.11	1.15	1.19	1.12	1.17	1.13	1.13	1.11	1.11	1.00	1.09	1.15	1.09	1.12
23	1.09	1.18	1.09	1.12	1.07	1.06	1.12	1.07	1.13	1.10	1.07	1.05	1.16	1.09	1.16	1.19	1.14	1.06	1.04	1.08	1.07	1.05	1.00	1.08	1.07	1.08
24	1.07	1.18	1.13	1.12	1.17	1.11	1.16	1.10	1.08	1.08	1.12	1.11	1.17	1.07	1.12	1.14	1.12	1.08	1.05	1.05	1.09	1.10	1.06	1.00	1.11	1.14
25	1.14	1.23	1.05	1.13	1.16	1.11	1.13	1.10	1.15	1.17	1.06	1.13	1.18	1.12	1.21	1.16	1.17	1.14	1.12	1.12	1.15	1.10	1.07	1.14	1.00	1.05
26	1.11	1.19	1.04	1.13	1.15	1.07	1.08	1.08	1.15	1.12	1.06	1.07	1.12	1.10	1.18	1.16	1.15	1.08	1.11	1.12	1.11	1.07	1.08	1.15	1.04	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	24	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Number wrong: 1 Percent Correct: 96.154

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (7 point linear regression)
3) acceleration cepstrum (7 point linear regression)
4)RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.02	1.20	1.16	1.16	1.24	1.10	1.26	1.12	1.11	1.09	1.24	1.07	1.22	1.20	1.21	1.19	1.19	1.02	1.07	1.07	1.00	1.17	1.10	1.08	1.20	1.18
2	1.13	1.00	1.21	1.18	1.29	1.17	1.21	1.12	1.21	1.14	1.14	1.14	1.17	1.15	1.06	1.20	1.18	1.18	1.18	1.14	1.13	1.19	1.20	1.17	1.22	1.23
3	1.15	1.28	1.00	1.17	1.26	1.12	1.17	1.15	1.17	1.15	1.13	1.18	1.19	1.24	1.27	1.16	1.18	1.21	1.17	1.17	1.14	1.12	1.11	1.26	1.14	1.11
4	1.17	1.32	1.22	1.00	1.42	1.18	1.20	1.14	1.23	1.28	1.16	1.16	1.19	1.21	1.29	1.27	1.23	1.22	1.19	1.22	1.14	1.07	1.25	1.25	1.17	1.16
5	1.15	1.40	1.12	1.25	1.00	1.07	1.16	1.22	1.27	1.19	1.22	1.06	1.36	1.21	1.32	1.23	1.23	1.14	1.13	1.16	1.14	1.19	1.10	1.17	1.18	1.16
6	1.15	1.24	1.13	1.23	1.11	1.01	1.16	1.16	1.19	1.11	1.14	1.00	1.23	1.12	1.20	1.21	1.18	1.08	1.10	1.15	1.04	1.17	1.13	1.14	1.17	1.16
7	1.13	1.37	1.06	1.25	1.21	1.10	1.00	1.14	1.20	1.21	1.15	1.16	1.20	1.23	1.31	1.21	1.23	1.20	1.14	1.24	1.11	1.08	1.11	1.22	1.10	1.09
8	1.08	1.13	1.11	1.11	1.24	1.10	1.10	1.00	1.08	1.12	1.10	1.08	1.06	1.11	1.12	1.12	1.08	1.10	1.10	1.09	1.06	1.04	1.09	1.11	1.13	1.16
9	1.06	1.19	1.11	1.19	1.22	1.09	1.26	1.10	1.01	1.07	1.24	1.15	1.17	1.14	1.17	1.14	1.07	1.09	1.00	1.04	1.04	1.15	1.06	1.00	1.15	1.15
10	1.10	1.17	1.07	1.13	1.20	1.09	1.15	1.13	1.08	1.00	1.16	1.11	1.10	1.13	1.14	1.09	1.15	1.07	1.03	1.03	1.03	1.11	1.05	1.05	1.18	1.18
11	1.18	1.29	1.06	1.15	1.19	1.13	1.16	1.14	1.17	1.21	1.00	1.14	1.21	1.18	1.25	1.20	1.24	1.20	1.14	1.18	1.18	1.11	1.10	1.21	1.05	1.07
12	1.17	1.25	1.22	1.23	1.25	1.16	1.23	1.20	1.27	1.19	1.15	1.00	1.20	1.13	1.20	1.34	1.27	1.17	1.25	1.22	1.12	1.18	1.24	1.22	1.18	1.22
13	1.20	1.22	1.14	1.15	1.41	1.15	1.17	1.13	1.13	1.18	1.17	1.21	1.00	1.22	1.23	1.17	1.19	1.26	1.17	1.21	1.21	1.10	1.17	1.23	1.22	1.17
14	1.13	1.24	1.07	1.11	1.10	1.08	1.12	1.07	1.14	1.12	1.07	1.07	1.18	1.00	1.12	1.17	1.12	1.09	1.04	1.03	1.08	1.06	1.03	1.07	1.04	1.10
15	1.14	1.15	1.23	1.24	1.38	1.23	1.33	1.16	1.31	1.10	1.19	1.18	1.24	1.12	1.00	1.27	1.25	1.20	1.18	1.12	1.11	1.25	1.17	1.17	1.25	1.25
16	1.16	1.25	1.14	1.07	1.38	1.13	1.14	1.15	1.07	1.16	1.13	1.15	1.12	1.19	1.26	1.00	1.10	1.28	1.10	1.13	1.15	1.11	1.17	1.18	1.17	1.20
17	1.09	1.20	1.08	1.14	1.20	1.04	1.13	1.10	1.04	1.04	1.16	1.07	1.18	1.10	1.20	1.04	1.00	1.15	1.05	1.05	1.07	1.11	1.08	1.05	1.16	1.12
18	1.07	1.17	1.18	1.21	1.25	1.12	1.26	1.11	1.19	1.07	1.20	1.05	1.20	1.12	1.11	1.24	1.20	1.00	1.10	1.07	1.01	1.14	1.09	1.10	1.20	1.18
19	1.13	1.27	1.07	1.18	1.17	1.04	1.26	1.13	1.09	1.19	1.20	1.11	1.22	1.21	1.31	1.12	1.13	1.13	1.00	1.08	1.10	1.17	1.06	1.15	1.17	1.16
20	1.12	1.27	1.13	1.22	1.20	1.14	1.28	1.13	1.16	1.11	1.24	1.14	1.29	1.20	1.21	1.24	1.19	1.09	1.06	1.00	1.06	1.20	1.10	1.04	1.15	1.19
21	1.18	1.28	1.18	1.31	1.34	1.19	1.30	1.23	1.20	1.18	1.29	1.16	1.30	1.21	1.22	1.27	1.25	1.16	1.19	1.17	1.00	1.20	1.21	1.17	1.27	1.25
22	1.15	1.33	1.09	1.09	1.32	1.14	1.19	1.12	1.16	1.16	1.14	1.20	1.15	1.21	1.28	1.18	1.20	1.21	1.18	1.15	1.15	1.00	1.12	1.23	1.15	1.17
23	1.13	1.32	1.14	1.16	1.11	1.09	1.15	1.09	1.18	1.14	1.13	1.06	1.25	1.13	1.24	1.29	1.20	1.09	1.06	1.10	1.07	1.06	1.00	1.13	1.09	1.13
24	1.09	1.29	1.14	1.14	1.21	1.14	1.24	1.13	1.08	1.09	1.17	1.14	1.23	1.08	1.15	1.20	1.13	1.12	1.04	1.04	1.09	1.12	1.06	1.00	1.15	1.20
25	1.18	1.35	1.07	1.17	1.23	1.16	1.18	1.13	1.19	1.23	1.09	1.18	1.25	1.16	1.28	1.22	1.22	1.21	1.16	1.18	1.19	1.13	1.10	1.22	1.00	1.08
26	1.15	1.30	1.06	1.16	1.21	1.10	1.11	1.11	1.21	1.17	1.11	1.11	1.17	1.17	1.26	1.25	1.21	1.12	1.14	1.18	1.15	1.10	1.12	1.26	1.07	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	21	2	3	4	5	12	7	8	24	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Number wrong: 3 Percent Correct: 88 462

This is the MSE ratios of 14th order:
1) liftered cepstrum24
2) delta cepstrum (7 point linear regression)
3) acceleration cepstrum (7 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00	1.11	1.06	1.10	1.17	1.08	1.15	1.05	1.07	1.09	1.08	1.06	1.06	1.09	1.08	1.09	1.07	1.06	1.07	1.10	1.06	1.06	1.05	1.05	1.07	1.09
2	1.09	1.00	1.07	1.12	1.18	1.10	1.19	1.04	1.12	1.07	1.07	1.08	1.08	1.10	1.05	1.11	1.09	1.07	1.10	1.03	1.09	1.10	1.07	1.06	1.05	1.08
3	1.08	1.16	1.00	1.09	1.14	1.06	1.16	1.12	1.12	1.06	1.04	1.07	1.10	1.15	1.15	1.10	1.11	1.08	1.09	1.08	1.11	1.09	1.08	1.09	1.04	1.06
4	1.10	1.18	1.15	1.00	1.19	1.09	1.12	1.08	1.14	1.16	1.10	1.11	1.08	1.11	1.14	1.19	1.15	1.13	1.11	1.12	1.11	1.06	1.11	1.12	1.07	1.13
5	1.17	1.28	1.08	1.19	1.00	1.08	1.16	1.24	1.23	1.15	1.17	1.08	1.23	1.15	1.24	1.19	1.21	1.08	1.16	1.17	1.17	1.18	1.12	1.14	1.07	1.10
6	1.11	1.14	1.03	1.10	1.04	1.00	1.10	1.06	1.15	1.07	1.05	1.01	1.10	1.05	1.11	1.14	1.09	1.04	1.07	1.09	1.08	1.08	1.04	1.08	1.04	1.08
7	1.07	1.18	1.04	1.08	1.11	1.07	1.00	1.08	1.11	1.11	1.08	1.04	1.11	1.07	1.13	1.14	1.13	1.07	1.12	1.12	1.09	1.07	1.05	1.06	1.06	1.09
8	1.06	1.08	1.11	1.17	1.22	1.12	1.13	1.00	1.07	1.12	1.06	1.08	1.02	1.09	1.10	1.13	1.09	1.07	1.08	1.06	1.07	1.03	1.07	1.05	1.09	1.15
9	1.02	1.09	1.04	1.17	1.20	1.12	1.16	1.06	1.00	1.06	1.08	1.15	1.05	1.12	1.11	1.10	1.07	1.04	1.05	1.04	1.05	1.05	1.06	1.03	1.11	1.10
10	1.04	1.11	1.02	1.12	1.10	1.07	1.14	1.08	1.08	1.00	1.09	1.07	1.09	1.07	1.10	1.09	1.08	1.02	1.06	1.04	1.06	1.06	1.02	1.01	1.04	1.05
11	1.11	1.15	1.06	1.11	1.14	1.07	1.13	1.08	1.12	1.12	1.00	1.06	1.08	1.08	1.10	1.09	1.15	1.04	1.10	1.10	1.11	1.06	1.05	1.08	1.03	1.04
12	1.08	1.09	1.05	1.10	1.14	1.06	1.11	1.04	1.15	1.08	1.04	1.00	1.09	1.04	1.04	1.16	1.12	1.03	1.12	1.08	1.08	1.09	1.07	1.06	1.06	1.10
13	1.12	1.12	1.08	1.21	1.25	1.15	1.22	1.07	1.07	1.13	1.07	1.12	1.00	1.19	1.10	1.09	1.17	1.10	1.13	1.07	1.08	1.00	1.13	1.08	1.12	1.11
14	1.08	1.13	1.08	1.08	1.10	1.09	1.06	1.05	1.17	1.09	1.06	1.05	1.10	1.00	1.09	1.17	1.10	1.06	1.12	1.09	1.10	1.06	1.04	1.06	1.06	1.10
15	1.10	1.14	1.15	1.17	1.26	1.18	1.20	1.09	1.17	1.13	1.10	1.10	1.13	1.05	1.00	1.22	1.19	1.12	1.19	1.15	1.10	1.14	1.14	1.09	1.16	1.18
16	1.08	1.12	1.08	1.11	1.21	1.11	1.17	1.06	1.03	1.08	1.04	1.13	1.00	1.16	1.10	1.03	1.10	1.08	1.08	1.06	1.08	1.02	1.09	1.06	1.09	1.09
17	1.03	1.08	1.03	1.08	1.05	1.01	1.08	1.05	1.04	1.02	1.04	1.02	1.03	1.03	1.09	1.03	1.01	1.02	1.02	1.05	1.03	1.00	1.02	1.01	1.04	1.05
18	1.04	1.06	1.06	1.18	1.17	1.09	1.13	1.04	1.08	1.05	1.05	1.03	1.05	1.08	1.04	1.15	1.07	1.00	1.09	1.03	1.02	1.03	1.05	1.04	1.12	1.14
19	1.07	1.14	1.08	1.12	1.10	1.07	1.18	1.11	1.07	1.08	1.09	1.14	1.12	1.15	1.19	1.09	1.09	1.07	1.00	1.06	1.14	1.10	1.03	1.10	1.05	1.07
20	1.07	1.10	1.10	1.19	1.19	1.15	1.16	1.07	1.11	1.06	1.10	1.13	1.10	1.14	1.14	1.21	1.11	1.06	1.07	1.00	1.09	1.09	1.08	1.04	1.11	1.15
21	1.14	1.18	1.09	1.30	1.21	1.15	1.20	1.16	1.13	1.14	1.16	1.11	1.16	1.18	1.14	1.19	1.14	1.08	1.17	1.15	1.00	1.12	1.13	1.11	1.18	1.20
22	1.06	1.15	1.03	1.07	1.12	1.05	1.08	1.04	1.06	1.09	1.03	1.05	1.03	1.11	1.12	1.09	1.10	1.06	1.06	1.06	1.05	1.00	1.04	1.06	1.03	1.07
23	1.10	1.12	1.05	1.10	1.05	1.05	1.11	1.06	1.12	1.08	1.06	1.06	1.07	1.08	1.12	1.15	1.12	1.05	1.03	1.05	1.10	1.04	1.00	1.05	1.01	1.09
24	1.02	1.12	1.07	1.07	1.11	1.06	1.09	1.04	1.07	1.06	1.06	1.07	1.06	1.03	1.06	1.11	1.06	1.03	1.05	1.02	1.06	1.02	1.03	1.00	1.08	1.08
25	1.12	1.18	1.04	1.11	1.10	1.07	1.12	1.11	1.15	1.12	1.05	1.08	1.13	1.12	1.17	1.12	1.14	1.08	1.10	1.09	1.14	1.09	1.04	1.10	1.00	1.05
26	1.09	1.16	1.04	1.11	1.11	1.05	1.07	1.07	1.14	1.10	1.03	1.03	1.09	1.06	1.11	1.13	1.14	1.04	1.13	1.09	1.10	1.06	1.05	1.08	1.04	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	13	22	18	19	20	21	22	23	24	25	26

Number wrong: 2 Percent Correct: 92.308

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (5 point linear regression)
3) acceleration cepstrum (5 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00	1.07	1.05	1.08	1.17	1.06	1.12	1.03	1.05	1.06	1.07	1.04	1.06	1.06	1.06	1.06	1.04	1.04	1.04	1.07	1.02	1.03	1.03	1.03	1.06	1.07
2	1.07	1.00	1.06	1.10	1.16	1.09	1.16	1.03	1.10	1.06	1.07	1.05	1.08	1.07	1.05	1.08	1.06	1.05	1.08	1.05	1.05	1.09	1.07	1.06	1.05	1.07
3	1.08	1.12	1.00	1.08	1.12	1.08	1.15	1.09	1.12	1.05	1.03	1.06	1.10	1.11	1.13	1.09	1.11	1.06	1.08	1.08	1.08	1.09	1.07	1.09	1.04	1.05
4	1.11	1.16	1.13	1.00	1.17	1.10	1.10	1.09	1.13	1.13	1.09	1.10	1.12	1.09	1.13	1.15	1.12	1.13	1.10	1.11	1.11	1.07	1.08	1.09	1.07	1.09
5	1.16	1.23	1.09	1.17	1.00	1.08	1.17	1.19	1.21	1.14	1.14	1.09	1.21	1.10	1.22	1.17	1.15	1.08	1.17	1.17	1.16	1.15	1.14	1.11	1.09	1.09
6	1.11	1.10	1.05	1.08	1.06	1.00	1.12	1.05	1.13	1.10	1.05	1.02	1.12	1.05	1.09	1.12	1.09	1.04	1.07	1.09	1.07	1.08	1.05	1.05	1.05	1.07
7	1.07	1.11	1.04	1.04	1.11	1.04	1.00	1.04	1.08	1.09	1.05	1.02	1.11	1.04	1.07	1.10	1.08	1.04	1.09	1.09	1.07	1.02	1.03	1.03	1.04	1.04
8	1.04	1.05	1.07	1.15	1.20	1.10	1.10	1.00	1.05	1.10	1.06	1.07	1.03	1.08	1.06	1.09	1.06	1.06	1.05	1.04	1.05	1.02	1.05	1.05	1.08	1.10
9	1.04	1.09	1.04	1.14	1.21	1.10	1.13	1.05	1.00	1.04	1.07	1.10	1.06	1.08	1.08	1.08	1.06	1.02	1.04	1.02	1.04	1.04	1.06	1.01	1.09	1.05
10	1.02	1.09	1.00	1.07	1.08	1.04	1.09	1.07	1.07	1.01	1.06	1.03	1.08	1.03	1.06	1.06	1.05	1.00	1.05	1.03	1.02	1.04	1.00	1.00	1.04	1.02
11	1.09	1.10	1.06	1.07	1.14	1.06	1.12	1.06	1.09	1.12	1.00	1.06	1.08	1.06	1.07	1.07	1.10	1.05	1.08	1.08	1.10	1.03	1.05	1.08	1.02	1.02
12	1.08	1.08	1.05	1.09	1.12	1.07	1.13	1.04	1.14	1.11	1.05	1.00	1.11	1.04	1.04	1.15	1.10	1.04	1.10	1.10	1.06	1.09	1.07	1.06	1.06	1.08
13	1.08	1.09	1.09	1.17	1.25	1.14	1.17	1.09	1.04	1.10	1.06	1.09	1.01	1.16	1.06	1.07	1.14	1.08	1.09	1.06	1.06	1.00	1.11	1.06	1.11	1.09
14	1.10	1.11	1.09	1.08	1.10	1.10	1.08	1.06	1.17	1.10	1.08	1.05	1.12	1.00	1.07	1.15	1.09	1.05	1.12	1.09	1.10	1.07	1.06	1.06	1.07	1.09
15	1.07	1.09	1.13	1.14	1.22	1.16	1.16	1.05	1.15	1.11	1.11	1.07	1.12	1.03	1.00	1.18	1.12	1.09	1.14	1.13	1.08	1.13	1.11	1.08	1.13	1.14
16	1.06	1.08	1.08	1.11	1.22	1.09	1.13	1.05	1.01	1.07	1.03	1.10	1.00	1.11	1.06	1.01	1.07	1.06	1.06	1.06	1.08	1.02	1.11	1.05	1.08	1.06
17	1.04	1.08	1.06	1.09	1.10	1.02	1.08	1.07	1.05	1.06	1.07	1.04	1.05	1.05	1.07	1.04	1.00	1.04	1.04	1.06	1.04	1.04	1.02	1.02	1.05	1.05
18	1.05	1.04	1.04	1.16	1.17	1.10	1.12	1.05	1.08	1.06	1.07	1.01	1.07	1.07	1.04	1.13	1.07	1.00	1.07	1.04	1.01	1.04	1.05	1.04	1.11	1.10
19	1.06	1.11	1.05	1.09	1.09	1.06	1.13	1.06	1.06	1.07	1.06	1.09	1.10	1.12	1.13	1.06	1.07	1.05	1.00	1.04	1.08	1.06	1.04	1.06	1.04	1.04
20	1.07	1.05	1.09	1.16	1.20	1.15	1.15	1.06	1.10	1.06	1.09	1.08	1.10	1.13	1.11	1.17	1.10	1.05	1.05	1.00	1.05	1.07	1.09	1.03	1.11	1.11
21	1.12	1.15	1.07	1.23	1.19	1.11	1.17	1.12	1.11	1.13	1.13	1.06	1.16	1.15	1.11	1.14	1.11	1.07	1.15	1.15	1.00	1.10	1.11	1.10	1.16	1.14
22	1.07	1.11	1.03	1.09	1.14	1.09	1.08	1.05	1.05	1.09	1.05	1.06	1.06	1.08	1.10	1.08	1.10	1.05	1.07	1.06	1.06	1.00	1.06	1.06	1.05	1.05
23	1.07	1.09	1.04	1.07	1.05	1.05	1.09	1.04	1.10	1.06	1.05	1.03	1.09	1.03	1.09	1.11	1.08	1.04	1.03	1.04	1.07	1.03	1.00	1.04	1.03	1.05
24	1.04	1.10	1.07	1.07	1.14	1.07	1.10	1.05	1.08	1.08	1.06	1.06	1.09	1.04	1.07	1.10	1.05	1.05	1.06	1.04	1.06	1.05	1.06	1.00	1.07	1.06
25	1.10	1.12	1.02	1.09	1.08	1.06	1.09	1.07	1.12	1.11	1.03	1.06	1.12	1.08	1.14	1.09	1.10	1.06	1.08	1.07	1.11	1.06	1.05	1.07	1.00	1.02
26	1.09	1.12	1.05	1.09	1.13	1.08	1.07	1.07	1.13	1.11	1.04	1.03	1.12	1.06	1.11	1.12	1.11	1.05	1.12	1.11	1.09	1.06	1.06	1.08	1.04	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	9	24	11	12	22	14	15	13	17	18	19	20	21	22	23	24	25	26

Number wrong: 3 Percent Correct: 88.462

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (5 point linear regression)
3) acceleration cepstrum (5 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 1, 2, 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00	1.19	1.23	1.18	1.52	1.23	1.43	1.19	1.15	1.17	1.21	1.20	1.20	1.16	1.12	1.20	1.18	1.12	1.23	1.08	1.09	1.26	1.12	1.07	1.28	1.17
2	1.17	1.00	1.24	1.26	1.41	1.21	1.35	1.22	1.31	1.15	1.21	1.16	1.22	1.15	1.08	1.18	1.21	1.16	1.22	1.12	1.14	1.30	1.16	1.15	1.19	1.18
3	1.13	1.24	1.00	1.10	1.27	1.13	1.15	1.13	1.14	1.09	1.07	1.13	1.11	1.20	1.26	1.13	1.13	1.09	1.11	1.16	1.11	1.11	1.09	1.21	1.09	1.07
4	1.10	1.33	1.27	1.00	1.59	1.31	1.33	1.17	1.14	1.28	1.16	1.27	1.15	1.26	1.21	1.29	1.25	1.23	1.27	1.15	1.18	1.18	1.16	1.17	1.20	1.15
5	1.30	1.44	1.19	1.35	1.00	1.11	1.37	1.31	1.31	1.24	1.32	1.15	1.38	1.23	1.46	1.32	1.28	1.15	1.21	1.30	1.24	1.28	1.18	1.22	1.19	1.26
6	1.20	1.25	1.13	1.23	1.09	1.00	1.25	1.13	1.25	1.14	1.15	1.04	1.22	1.11	1.24	1.25	1.17	1.06	1.11	1.16	1.14	1.18	1.08	1.13	1.12	1.19
7	1.08	1.18	1.11	1.07	1.30	1.12	1.00	1.04	1.10	1.17	1.08	1.13	1.10	1.24	1.23	1.21	1.19	1.09	1.17	1.08	1.09	1.04	1.06	1.09	1.12	1.07
8	1.07	1.18	1.17	1.16	1.34	1.14	1.17	1.00	1.14	1.17	1.11	1.14	1.05	1.15	1.13	1.21	1.17	1.10	1.19	1.06	1.08	1.05	1.10	1.08	1.18	1.17
9	1.05	1.22	1.18	1.18	1.43	1.18	1.43	1.14	1.06	1.11	1.23	1.18	1.19	1.15	1.19	1.17	1.14	1.10	1.15	1.01	1.07	1.18	1.09	1.01	1.31	1.15
10	1.04	1.18	1.10	1.11	1.26	1.08	1.29	1.12	1.11	1.02	1.15	1.08	1.14	1.08	1.14	1.13	1.11	1.03	1.11	1.02	1.01	1.13	1.03	1.01	1.17	1.12
11	1.13	1.24	1.11	1.10	1.26	1.13	1.16	1.08	1.15	1.21	1.00	1.14	1.11	1.17	1.18	1.19	1.19	1.11	1.16	1.13	1.14	1.10	1.09	1.17	1.06	1.03
12	1.06	1.11	1.16	1.19	1.26	1.10	1.34	1.13	1.21	1.10	1.15	1.01	1.18	1.02	1.06	1.19	1.17	1.04	1.18	1.07	1.05	1.19	1.09	1.07	1.16	1.16
13	1.12	1.20	1.17	1.19	1.39	1.19	1.19	1.11	1.13	1.18	1.13	1.17	1.00	1.28	1.18	1.20	1.23	1.14	1.18	1.12	1.11	1.06	1.15	1.13	1.17	1.14
14	1.15	1.16	1.20	1.19	1.24	1.11	1.31	1.14	1.27	1.12	1.17	1.09	1.21	1.00	1.09	1.22	1.18	1.07	1.18	1.08	1.14	1.20	1.09	1.08	1.18	1.17
15	1.15	1.14	1.30	1.27	1.48	1.21	1.41	1.18	1.35	1.18	1.25	1.18	1.26	1.10	1.00	1.26	1.31	1.16	1.31	1.15	1.17	1.28	1.16	1.16	1.30	1.25
16	1.07	1.21	1.13	1.07	1.43	1.18	1.22	1.09	1.02	1.13	1.08	1.18	1.05	1.22	1.15	1.06	1.11	1.11	1.13	1.07	1.12	1.08	1.13	1.12	1.11	1.08
17	1.06	1.13	1.14	1.15	1.27	1.06	1.29	1.13	1.11	1.07	1.14	1.09	1.16	1.08	1.10	1.09	1.04	1.07	1.09	1.04	1.07	1.18	1.03	1.02	1.16	1.12
18	1.10	1.17	1.19	1.26	1.33	1.12	1.33	1.11	1.23	1.11	1.21	1.05	1.15	1.11	1.14	1.23	1.22	1.00	1.18	1.08	1.04	1.14	1.09	1.11	1.23	1.22
19	1.11	1.20	1.10	1.14	1.13	1.05	1.27	1.09	1.11	1.08	1.14	1.07	1.15	1.17	1.29	1.10	1.09	1.04	1.00	1.09	1.08	1.12	1.03	1.11	1.10	1.11
20	1.16	1.20	1.20	1.22	1.31	1.13	1.40	1.11	1.20	1.11	1.23	1.10	1.23	1.17	1.21	1.25	1.21	1.07	1.14	1.00	1.08	1.17	1.10	1.08	1.22	1.21
21	1.21	1.26	1.22	1.32	1.33	1.15	1.38	1.22	1.23	1.16	1.28	1.10	1.26	1.22	1.26	1.22	1.22	1.11	1.19	1.18	1.00	1.20	1.15	1.17	1.30	1.27
22	1.07	1.25	1.12	1.05	1.32	1.15	1.13	1.05	1.09	1.17	1.08	1.15	1.05	1.22	1.20	1.19	1.18	1.10	1.17	1.08	1.08	1.00	1.09	1.09	1.11	1.11
23	1.21	1.25	1.14	1.19	1.09	1.05	1.22	1.10	1.21	1.15	1.13	1.07	1.17	1.11	1.22	1.28	1.22	1.07	1.09	1.11	1.15	1.12	1.00	1.11	1.08	1.15
24	1.07	1.28	1.21	1.17	1.41	1.16	1.43	1.15	1.16	1.15	1.20	1.19	1.25	1.14	1.14	1.23	1.17	1.12	1.22	1.04	1.14	1.24	1.11	1.01	1.31	1.21
25	1.24	1.26	1.08	1.17	1.19	1.14	1.18	1.16	1.23	1.22	1.07	1.13	1.22	1.24	1.29	1.20	1.21	1.15	1.15	1.16	1.22	1.17	1.08	1.24	1.00	1.04
26	1.14	1.23	1.10	1.11	1.27	1.12	1.13	1.09	1.18	1.18	1.06	1.08	1.11	1.16	1.20	1.21	1.19	1.08	1.17	1.13	1.13	1.12	1.07	1.19	1.06	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	24	24	11	12	13	14	15	9	24	18	19	20	21	22	23	24	25	26

Number wrong: 4 Percent Correct: 84.615

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (5 point linear regression)
3) acceleration cepstrum (5 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 1, 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00	1.26	1.32	1.23	1.69	1.31	1.59	1.27	1.20	1.22	1.28	1.27	1.27	1.21	1.15	1.27	1.23	1.15	1.32	1.10	1.12	1.37	1.15	1.09	1.40	1.23
2	1.21	1.00	1.31	1.33	1.53	1.26	1.45	1.29	1.41	1.18	1.28	1.20	1.28	1.18	1.08	1.23	1.27	1.21	1.29	1.16	1.17	1.40	1.20	1.20	1.24	1.23
3	1.15	1.31	1.00	1.12	1.35	1.15	1.15	1.15	1.17	1.10	1.08	1.16	1.13	1.26	1.32	1.16	1.13	1.09	1.13	1.21	1.13	1.12	1.10	1.27	1.12	1.09
4	1.10	1.42	1.33	1.00	1.81	1.41	1.44	1.22	1.15	1.35	1.20	1.34	1.17	1.34	1.25	1.38	1.28	1.26	1.35	1.16	1.21	1.24	1.19	1.22	1.26	1.16
5	1.37	1.57	1.26	1.47	1.00	1.15	1.48	1.39	1.38	1.29	1.42	1.19	1.48	1.30	1.59	1.41	1.34	1.19	1.25	1.39	1.29	1.36	1.22	1.28	1.25	1.36
6	1.25	1.34	1.17	1.29	1.11	1.00	1.33	1.16	1.32	1.16	1.20	1.05	1.27	1.15	1.31	1.32	1.21	1.07	1.13	1.20	1.17	1.23	1.10	1.17	1.16	1.25
7	1.08	1.23	1.13	1.07	1.39	1.14	1.00	1.04	1.10	1.20	1.10	1.17	1.10	1.33	1.30	1.27	1.24	1.10	1.21	1.08	1.09	1.04	1.07	1.11	1.16	1.07
8	1.09	1.26	1.22	1.17	1.44	1.18	1.23	1.00	1.18	1.21	1.16	1.19	1.07	1.20	1.17	1.28	1.23	1.13	1.26	1.08	1.10	1.08	1.12	1.11	1.24	1.22
9	1.06	1.29	1.25	1.20	1.56	1.23	1.58	1.19	1.09	1.15	1.31	1.22	1.26	1.18	1.24	1.22	1.16	1.13	1.21	1.01	1.08	1.26	1.10	1.02	1.43	1.22
10	1.05	1.24	1.15	1.12	1.36	1.11	1.39	1.16	1.14	1.02	1.20	1.11	1.19	1.10	1.17	1.18	1.13	1.04	1.13	1.02	1.01	1.18	1.03	1.01	1.24	1.17
11	1.13	1.30	1.11	1.10	1.32	1.15	1.18	1.08	1.17	1.24	1.00	1.16	1.13	1.21	1.21	1.25	1.20	1.12	1.19	1.15	1.15	1.11	1.08	1.20	1.06	1.03
12	1.05	1.15	1.22	1.23	1.35	1.11	1.46	1.18	1.26	1.10	1.20	1.01	1.21	1.02	1.07	1.23	1.21	1.05	1.23	1.07	1.04	1.26	1.10	1.08	1.21	1.20
13	1.14	1.25	1.21	1.20	1.49	1.23	1.21	1.13	1.18	1.22	1.18	1.21	1.00	1.35	1.23	1.26	1.27	1.17	1.23	1.15	1.13	1.08	1.17	1.17	1.20	1.17
14	1.18	1.20	1.26	1.25	1.32	1.13	1.42	1.19	1.34	1.16	1.23	1.12	1.27	1.00	1.11	1.27	1.24	1.08	1.22	1.09	1.17	1.27	1.11	1.10	1.23	1.21
15	1.20	1.19	1.41	1.36	1.66	1.27	1.57	1.27	1.48	1.23	1.36	1.25	1.35	1.15	1.00	1.33	1.41	1.23	1.42	1.19	1.23	1.38	1.22	1.22	1.41	1.34
16	1.06	1.25	1.14	1.06	1.54	1.20	1.26	1.10	1.02	1.15	1.10	1.20	1.06	1.26	1.17	1.09	1.11	1.13	1.16	1.08	1.12	1.12	1.13	1.14	1.12	1.08
17	1.07	1.16	1.18	1.19	1.37	1.07	1.40	1.17	1.14	1.08	1.20	1.11	1.22	1.10	1.11	1.11	1.04	1.09	1.13	1.03	1.07	1.24	1.04	1.03	1.22	1.16
18	1.12	1.22	1.26	1.29	1.42	1.13	1.44	1.13	1.31	1.13	1.28	1.07	1.20	1.13	1.18	1.29	1.28	1.00	1.23	1.09	1.06	1.19	1.09	1.13	1.31	1.28
19	1.14	1.28	1.12	1.17	1.17	1.05	1.35	1.11	1.13	1.10	1.19	1.06	1.19	1.21	1.38	1.12	1.10	1.05	1.00	1.12	1.08	1.16	1.03	1.15	1.13	1.16
20	1.21	1.28	1.27	1.26	1.38	1.13	1.52	1.14	1.26	1.14	1.31	1.11	1.30	1.20	1.27	1.30	1.26	1.08	1.19	1.00	1.09	1.22	1.11	1.10	1.30	1.27
21	1.26	1.32	1.28	1.37	1.41	1.17	1.50	1.27	1.29	1.16	1.36	1.12	1.33	1.26	1.33	1.26	1.25	1.14	1.22	1.21	1.00	1.25	1.17	1.20	1.39	1.34
22	1.07	1.32	1.15	1.04	1.42	1.20	1.16	1.06	1.10	1.20	1.10	1.19	1.04	1.29	1.25	1.25	1.21	1.12	1.21	1.09	1.08	1.00	1.10	1.11	1.15	1.13
23	1.29	1.36	1.20	1.24	1.12	1.06	1.29	1.13	1.28	1.20	1.18	1.09	1.22	1.13	1.29	1.37	1.29	1.10	1.13	1.14	1.20	1.16	1.00	1.15	1.10	1.21
24	1.08	1.39	1.27	1.19	1.56	1.20	1.60	1.19	1.19	1.19	1.28	1.25	1.32	1.18	1.17	1.30	1.21	1.16	1.30	1.02	1.16	1.32	1.13	1.01	1.43	1.27
25	1.31	1.34	1.11	1.21	1.25	1.18	1.23	1.19	1.30	1.27	1.09	1.16	1.27	1.32	1.36	1.25	1.25	1.20	1.18	1.21	1.27	1.21	1.11	1.33	1.00	1.05
26	1.17	1.30	1.14	1.13	1.36	1.15	1.17	1.11	1.23	1.23	1.08	1.11	1.12	1.23	1.25	1.27	1.24	1.10	1.22	1.18	1.17	1.15	1.09	1.26	1.09	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	20	24	11	12	13	14	15	9	20	18	19	20	21	22	23	24	25	26

Number wrong: 4 Percent Correct: 84.615

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (7 point linear regression)
3) acceleration cepstrum (7 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 1, 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00	1.25	1.33	1.23	1.69	1.31	1.58	1.26	1.20	1.23	1.28	1.28	1.27	1.21	1.15	1.27	1.25	1.16	1.33	1.08	1.12	1.37	1.16	1.09	1.39	1.22
2	1.22	1.00	1.33	1.35	1.53	1.28	1.45	1.31	1.42	1.19	1.28	1.21	1.29	1.19	1.09	1.24	1.28	1.22	1.30	1.16	1.19	1.40	1.20	1.20	1.26	1.24
3	1.16	1.30	1.00	1.11	1.34	1.15	1.15	1.15	1.16	1.10	1.08	1.16	1.11	1.25	1.32	1.16	1.14	1.10	1.13	1.21	1.13	1.11	1.10	1.26	1.11	1.08
4	1.10	1.41	1.35	1.00	1.80	1.42	1.44	1.22	1.15	1.35	1.19	1.35	1.17	1.35	1.24	1.37	1.31	1.27	1.35	1.16	1.22	1.23	1.20	1.21	1.26	1.17
5	1.37	1.54	1.24	1.45	1.00	1.13	1.47	1.37	1.36	1.29	1.42	1.19	1.46	1.29	1.58	1.39	1.35	1.19	1.23	1.37	1.28	1.35	1.20	1.27	1.25	1.34
6	1.25	1.33	1.18	1.30	1.10	1.00	1.31	1.17	1.31	1.15	1.20	1.05	1.26	1.15	1.31	1.31	1.22	1.08	1.13	1.19	1.17	1.23	1.09	1.17	1.15	1.25
7	1.09	1.22	1.15	1.08	1.39	1.15	1.00	1.04	1.11	1.20	1.10	1.19	1.10	1.34	1.30	1.26	1.25	1.12	1.21	1.07	1.10	1.04	1.08	1.11	1.16	1.09
8	1.09	1.24	1.22	1.17	1.41	1.16	1.21	1.00	1.18	1.21	1.14	1.18	1.05	1.18	1.17	1.27	1.23	1.12	1.26	1.07	1.10	1.07	1.12	1.10	1.23	1.21
9	1.05	1.29	1.25	1.19	1.53	1.22	1.58	1.19	1.09	1.14	1.31	1.22	1.25	1.18	1.24	1.21	1.18	1.13	1.21	1.01	1.09	1.24	1.10	1.01	1.41	1.20
10	1.05	1.23	1.15	1.12	1.35	1.10	1.38	1.15	1.13	1.02	1.20	1.10	1.18	1.10	1.18	1.17	1.14	1.04	1.14	1.01	1.01	1.18	1.04	1.01	1.23	1.17
11	1.16	1.31	1.13	1.12	1.32	1.17	1.19	1.09	1.18	1.26	1.00	1.18	1.13	1.22	1.24	1.26	1.23	1.14	1.20	1.16	1.16	1.14	1.10	1.21	1.08	1.04
12	1.05	1.13	1.22	1.24	1.33	1.11	1.44	1.18	1.24	1.09	1.20	1.01	1.21	1.01	1.07	1.21	1.20	1.04	1.22	1.06	1.04	1.25	1.09	1.07	1.21	1.20
13	1.14	1.25	1.21	1.20	1.46	1.22	1.20	1.12	1.18	1.23	1.17	1.21	1.00	1.33	1.24	1.26	1.28	1.17	1.23	1.15	1.13	1.09	1.17	1.17	1.19	1.16
14	1.17	1.18	1.26	1.25	1.30	1.12	1.42	1.18	1.32	1.14	1.22	1.11	1.25	1.00	1.09	1.25	1.23	1.07	1.20	1.07	1.15	1.27	1.10	1.09	1.23	1.21
15	1.19	1.16	1.39	1.34	1.61	1.24	1.53	1.25	1.46	1.21	1.33	1.23	1.33	1.14	1.00	1.30	1.41	1.20	1.39	1.16	1.22	1.35	1.19	1.20	1.38	1.31
16	1.07	1.27	1.15	1.05	1.54	1.22	1.26	1.10	1.03	1.16	1.11	1.22	1.07	1.27	1.19	1.09	1.13	1.14	1.16	1.08	1.14	1.11	1.14	1.16	1.12	1.09
17	1.07	1.15	1.18	1.18	1.36	1.08	1.40	1.15	1.14	1.07	1.18	1.11	1.22	1.10	1.12	1.11	1.06	1.08	1.12	1.03	1.08	1.24	1.03	1.02	1.22	1.16
18	1.13	1.23	1.26	1.30	1.41	1.13	1.44	1.14	1.30	1.14	1.28	1.07	1.19	1.13	1.19	1.28	1.30	1.01	1.23	1.10	1.05	1.18	1.10	1.14	1.30	1.27
19	1.13	1.25	1.12	1.17	1.16	1.04	1.34	1.11	1.13	1.09	1.18	1.06	1.18	1.20	1.36	1.11	1.10	1.04	1.00	1.12	1.08	1.15	1.03	1.14	1.13	1.15
20	1.20	1.27	1.26	1.26	1.37	1.12	1.52	1.14	1.25	1.14	1.30	1.10	1.30	1.19	1.26	1.28	1.27	1.08	1.19	1.00	1.10	1.21	1.10	1.10	1.27	1.25
21	1.26	1.31	1.29	1.36	1.39	1.17	1.48	1.27	1.29	1.17	1.36	1.11	1.31	1.25	1.34	1.26	1.27	1.14	1.21	1.20	1.00	1.25	1.17	1.21	1.37	1.33
22	1.07	1.32	1.16	1.04	1.42	1.18	1.15	1.05	1.11	1.21	1.09	1.20	1.04	1.30	1.25	1.24	1.22	1.13	1.22	1.09	1.09	1.00	1.10	1.11	1.14	1.14
23	1.28	1.34	1.20	1.24	1.11	1.05	1.29	1.14	1.27	1.20	1.16	1.09	1.21	1.14	1.29	1.36	1.29	1.09	1.13	1.15	1.20	1.16	1.00	1.15	1.11	1.20
24	1.08	1.38	1.29	1.21	1.55	1.21	1.59	1.20	1.19	1.19	1.27	1.26	1.33	1.19	1.18	1.30	1.23	1.15	1.30	1.03	1.18	1.33	1.13	1.01	1.43	1.28
25	1.31	1.34	1.11	1.21	1.25	1.17	1.23	1.20	1.29	1.27	1.09	1.17	1.26	1.32	1.36	1.25	1.26	1.20	1.18	1.21	1.27	1.22	1.10	1.33	1.00	1.05
26	1.16	1.28	1.12	1.13	1.33	1.13	1.16	1.10	1.21	1.21	1.07	1.11	1.11	1.21	1.24	1.25	1.24	1.09	1.20	1.15	1.15	1.14	1.07	1.24	1.07	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	20	21	11	12	13	14	15	9	24	18	19	20	21	22	23	24	25	26

Number wrong: 4 Percent Correct: 84.615

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (7 point linear regression)
3) acceleration cepstrum (7 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00	1.45	1.59	1.37	2.22	1.56	2.07	1.51	1.35	1.38	1.50	1.50	1.49	1.37	1.24	1.49	1.43	1.26	1.61	1.13	1.21	1.72	1.26	1.16	1.73	1.39
2	1.35	1.00	1.56	1.56	1.90	1.42	1.75	1.56	1.72	1.29	1.49	1.34	1.49	1.29	1.12	1.39	1.47	1.38	1.50	1.27	1.29	1.71	1.33	1.34	1.44	1.39
3	1.22	1.49	1.00	1.16	1.58	1.23	1.15	1.22	1.22	1.15	1.12	1.25	1.16	1.41	1.50	1.24	1.15	1.13	1.17	1.34	1.18	1.15	1.14	1.44	1.20	1.14
4	1.10	1.68	1.53	1.00	2.45	1.73	1.79	1.34	1.17	1.57	1.31	1.58	1.22	1.60	1.38	1.60	1.44	1.40	1.60	1.22	1.30	1.41	1.30	1.35	1.44	1.24
5	1.59	1.91	1.43	1.78	1.00	1.21	1.79	1.59	1.56	1.44	1.71	1.30	1.74	1.49	1.96	1.65	1.53	1.31	1.33	1.62	1.42	1.58	1.30	1.45	1.42	1.62
6	1.40	1.57	1.30	1.50	1.15	1.00	1.54	1.27	1.51	1.21	1.35	1.09	1.42	1.26	1.52	1.52	1.34	1.11	1.20	1.30	1.26	1.38	1.14	1.29	1.26	1.43
7	1.10	1.34	1.22	1.10	1.66	1.24	1.00	1.03	1.11	1.31	1.16	1.31	1.09	1.62	1.52	1.45	1.39	1.17	1.33	1.06	1.12	1.05	1.12	1.19	1.28	1.10
8	1.14	1.47	1.36	1.20	1.67	1.26	1.35	1.00	1.32	1.32	1.26	1.31	1.11	1.32	1.29	1.48	1.40	1.21	1.47	1.12	1.15	1.14	1.19	1.17	1.39	1.35
9	1.09	1.50	1.46	1.26	1.91	1.35	2.04	1.33	1.17	1.25	1.56	1.34	1.46	1.29	1.40	1.37	1.27	1.24	1.38	1.00	1.13	1.48	1.14	1.02	1.77	1.38
10	1.08	1.39	1.29	1.17	1.63	1.18	1.69	1.25	1.20	1.04	1.34	1.18	1.30	1.16	1.29	1.31	1.21	1.07	1.22	1.00	1.00	1.32	1.05	1.02	1.45	1.32
11	1.18	1.50	1.17	1.13	1.50	1.25	1.25	1.11	1.24	1.36	1.00	1.26	1.17	1.36	1.36	1.43	1.30	1.18	1.30	1.21	1.20	1.20	1.11	1.32	1.10	1.03
12	1.03	1.23	1.38	1.38	1.57	1.16	1.79	1.31	1.39	1.09	1.34	1.02	1.32	1.00	1.10	1.32	1.31	1.05	1.35	1.05	1.03	1.44	1.12	1.09	1.36	1.32
13	1.21	1.41	1.33	1.23	1.74	1.32	1.25	1.17	1.31	1.35	1.30	1.34	1.00	1.53	1.40	1.45	1.40	1.26	1.36	1.25	1.21	1.17	1.23	1.27	1.29	1.26
14	1.27	1.30	1.44	1.42	1.53	1.16	1.76	1.31	1.52	1.21	1.39	1.18	1.41	1.00	1.15	1.40	1.39	1.10	1.32	1.08	1.24	1.47	1.16	1.14	1.38	1.33
15	1.34	1.29	1.70	1.58	2.10	1.39	1.97	1.49	1.82	1.35	1.62	1.44	1.57	1.27	1.00	1.48	1.69	1.37	1.70	1.26	1.38	1.63	1.32	1.36	1.69	1.54
16	1.06	1.43	1.20	1.00	1.87	1.31	1.39	1.16	1.02	1.22	1.16	1.31	1.11	1.41	1.28	1.18	1.14	1.19	1.25	1.10	1.17	1.22	1.15	1.23	1.16	1.10
17	1.10	1.23	1.31	1.28	1.64	1.11	1.72	1.26	1.22	1.11	1.33	1.17	1.39	1.16	1.15	1.18	1.09	1.13	1.22	1.00	1.11	1.45	1.05	1.04	1.38	1.28
18	1.20	1.40	1.47	1.41	1.66	1.16	1.77	1.21	1.53	1.21	1.49	1.13	1.33	1.19	1.32	1.45	1.49	1.00	1.39	1.14	1.10	1.33	1.13	1.22	1.51	1.45
19	1.22	1.45	1.19	1.26	1.25	1.04	1.56	1.17	1.21	1.14	1.32	1.03	1.28	1.31	1.62	1.19	1.14	1.05	1.00	1.20	1.09	1.25	1.01	1.24	1.23	1.27
20	1.35	1.50	1.45	1.36	1.56	1.12	1.89	1.22	1.41	1.21	1.52	1.14	1.50	1.26	1.43	1.42	1.43	1.12	1.33	1.00	1.13	1.36	1.13	1.18	1.48	1.43
21	1.41	1.48	1.49	1.50	1.62	1.22	1.82	1.42	1.47	1.20	1.59	1.18	1.49	1.37	1.56	1.37	1.39	1.21	1.28	1.28	1.00	1.41	1.24	1.30	1.62	1.53
22	1.06	1.52	1.26	1.00	1.70	1.31	1.24	1.07	1.15	1.32	1.15	1.32	1.02	1.51	1.40	1.42	1.31	1.19	1.36	1.11	1.10	1.00	1.14	1.16	1.24	1.20
23	1.50	1.63	1.35	1.40	1.19	1.08	1.49	1.22	1.46	1.34	1.30	1.14	1.35	1.24	1.49	1.64	1.49	1.15	1.23	1.25	1.33	1.28	1.00	1.26	1.17	1.37
24	1.12	1.68	1.47	1.32	1.98	1.34	2.09	1.33	1.30	1.31	1.49	1.44	1.56	1.32	1.27	1.51	1.36	1.27	1.54	1.00	1.26	1.58	1.20	1.03	1.79	1.48
25	1.52	1.57	1.20	1.33	1.42	1.30	1.37	1.32	1.48	1.44	1.15	1.26	1.41	1.56	1.59	1.41	1.39	1.33	1.27	1.36	1.43	1.36	1.17	1.59	1.00	1.07
26	1.25	1.47	1.23	1.16	1.58	1.23	1.26	1.16	1.34	1.35	1.13	1.20	1.13	1.40	1.38	1.43	1.37	1.15	1.32	1.24	1.25	1.24	1.11	1.43	1.14	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	8	20	20	11	14	13	14	15	4	20	18	19	20	21	22	23	20	25	26

Number wrong: 6 Percent Correct: 76.923

This is the MSE ratios of 14th order:
1) liftered cepstrum
2) delta cepstrum (5 point linear regression)
3) acceleration cepstrum (5 point linear regression)
4) RASTA and liftered cepstrum

These results are from 32 msec Hamming windowed frames at a 16 msec frame rate. The algorithm is the generalized Lloyd's VQ algorithm with 40 codewords/codebook.

The following features were used: 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1.00	1.05	1.06	1.10	1.16	1.07	1.09	1.02	1.05	1.07	1.06	1.06	1.05	1.06	1.06	1.05	1.07	1.05	1.04	1.03	1.04	1.02	1.05	1.02	1.06	1.06
2	1.08	1.00	1.09	1.14	1.15	1.13	1.16	1.06	1.11	1.09	1.07	1.09	1.09	1.08	1.06	1.09	1.09	1.07	1.10	1.05	1.09	1.09	1.07	1.07	1.07	1.08
3	1.10	1.11	1.00	1.06	1.10	1.08	1.14	1.08	1.10	1.06	1.05	1.06	1.07	1.09	1.14	1.07	1.13	1.08	1.08	1.07	1.08	1.07	1.06	1.08	1.02	1.03
4	1.10	1.14	1.17	1.00	1.16	1.10	1.10	1.09	1.13	1.14	1.07	1.12	1.13	1.10	1.11	1.13	1.17	1.15	1.10	1.11	1.14	1.06	1.09	1.07	1.07	1.11
5	1.15	1.17	1.06	1.12	1.00	1.04	1.14	1.16	1.16	1.14	1.13	1.07	1.18	1.09	1.19	1.12	1.16	1.07	1.13	1.12	1.14	1.13	1.10	1.08	1.08	1.07
6	1.10	1.08	1.05	1.10	1.04	1.00	1.09	1.06	1.11	1.09	1.04	1.02	1.11	1.03	1.10	1.10	1.09	1.04	1.06	1.08	1.07	1.08	1.05	1.05	1.04	1.08
7	1.08	1.10	1.07	1.07	1.11	1.07	1.00	1.04	1.11	1.10	1.04	1.06	1.10	1.05	1.09	1.08	1.11	1.06	1.10	1.08	1.08	1.04	1.04	1.03	1.05	1.08
8	1.04	1.02	1.09	1.14	1.15	1.07	1.07	1.00	1.04	1.09	1.02	1.06	1.00	1.04	1.05	1.06	1.06	1.03	1.05	1.03	1.04	1.01	1.05	1.03	1.06	1.07
9	1.01	1.07	1.05	1.13	1.16	1.08	1.12	1.05	1.01	1.04	1.06	1.10	1.04	1.07	1.08	1.06	1.10	1.03	1.04	1.02	1.05	1.01	1.06	1.00	1.06	1.02
10	1.03	1.07	1.00	1.08	1.06	1.02	1.08	1.05	1.05	1.01	1.05	1.02	1.05	1.04	1.07	1.03	1.07	1.01	1.06	1.03	1.02	1.03	1.02	1.00	1.02	1.02
11	1.13	1.11	1.09	1.10	1.15	1.09	1.12	1.08	1.11	1.15	1.00	1.11	1.09	1.08	1.12	1.08	1.15	1.09	1.10	1.11	1.11	1.07	1.09	1.10	1.06	1.05
12	1.06	1.04	1.06	1.10	1.09	1.06	1.10	1.05	1.09	1.09	1.05	1.00	1.10	1.02	1.04	1.10	1.10	1.03	1.09	1.07	1.06	1.05	1.07	1.05	1.05	1.08
13	1.07	1.09	1.09	1.17	1.19	1.13	1.14	1.07	1.04	1.10	1.04	1.09	1.00	1.13	1.08	1.07	1.15	1.08	1.09	1.04	1.05	1.01	1.11	1.07	1.09	1.06
14	1.07	1.06	1.07	1.08	1.08	1.08	1.07	1.04	1.11	1.06	1.05	1.05	1.10	1.00	1.03	1.10	1.07	1.05	1.09	1.07	1.07	1.07	1.04	1.03	1.07	1.09
15	1.04	1.03	1.08	1.10	1.12	1.09	1.08	1.01	1.10	1.07	1.04	1.03	1.09	1.00	1.00	1.11	1.12	1.03	1.08	1.06	1.06	1.06	1.06	1.03	1.08	1.08
16	1.08	1.12	1.10	1.11	1.21	1.13	1.13	1.05	1.03	1.10	1.05	1.13	1.02	1.12	1.10	1.00	1.12	1.09	1.07	1.05	1.11	1.00	1.13	1.10	1.08	1.07
17	1.04	1.06	1.05	1.08	1.08	1.04	1.07	1.05	1.06	1.04	1.04	1.05	1.05	1.03	1.08	1.04	1.02	1.03	1.02	1.05	1.06	1.04	1.02	1.00	1.05	1.04
18	1.06	1.06	1.05	1.19	1.15	1.09	1.11	1.06	1.07	1.08	1.07	1.00	1.06	1.07	1.06	1.12	1.10	1.01	1.07	1.06	1.00	1.03	1.07	1.05	1.08	1.09
19	1.05	1.06	1.05	1.08	1.06	1.04	1.12	1.05	1.05	1.05	1.04	1.08	1.07	1.10	1.11	1.04	1.07	1.03	1.00	1.04	1.08	1.05	1.04	1.04	1.03	1.03
20	1.05	1.04	1.08	1.16	1.17	1.12	1.16	1.05	1.09	1.06	1.08	1.07	1.09	1.12	1.09	1.15	1.11	1.05	1.05	1.00	1.06	1.07	1.08	1.02	1.06	1.07
21	1.12	1.14	1.10	1.22	1.17	1.11	1.15	1.12	1.10	1.14	1.12	1.05	1.13	1.14	1.12	1.15	1.15	1.06	1.14	1.13	1.00	1.10	1.11	1.12	1.12	1.13
22	1.07	1.13	1.05	1.08	1.13	1.06	1.07	1.04	1.06	1.09	1.04	1.08	1.06	1.09	1.10	1.06	1.13	1.06	1.07	1.07	1.08	1.00	1.06	1.06	1.04	1.07
23	1.06	1.05	1.04	1.09	1.04	1.03	1.08	1.05	1.08	1.06	1.02	1.03	1.07	1.05	1.09	1.09	1.08	1.03	1.02	1.05	1.06	1.03	1.00	1.03	1.04	1.03
24	1.05	1.07	1.11	1.11	1.12	1.07	1.09	1.07	1.09	1.07	1.06	1.08	1.10	1.05	1.09	1.08	1.11	1.04	1.06	1.07	1.09	1.07	1.06	1.00	1.08	1.09
25	1.10	1.10	1.03	1.09	1.08	1.05	1.09	1.08	1.10	1.10	1.03	1.08	1.11	1.08	1.14	1.09	1.13	1.07	1.09	1.06	1.11	1.07	1.04	1.07	1.00	1.02
26	1.07	1.09	1.01	1.09	1.09	1.04	1.05	1.04	1.08	1.07	1.01	1.02	1.08	1.03	1.10	1.07	1.10	1.04	1.08	1.05	1.06	1.05	1.03	1.04	1.01	1.00

Speaker:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Recognized As:	1	2	3	4	5	6	7	13	24	3	11	12	13	14	15	22	24	12	19	20	21	22	23	24	25	26

Number wrong: 6 Percent Correct: 76.923

GREENFLAG Database Results

With Cepstrum and Delta Cepstrum

```
With cepstrum: Speaker ccd064 Detected as ccd Wrong 0
With delta: Speaker ccd064 Detected as ccd Wrong 0
With both: Speaker ccd064 Detected as ccd Wrong 0

With cepstrum: Speaker ccd078 Detected as cdn Wrong 1
With delta: Speaker ccd078 Detected as ccz Wrong 1
With both: Speaker ccd078 Detected as ccz Wrong 1

With cepstrum: Speaker ccd094 Detected as ccd Wrong 1
With delta: Speaker ccd094 Detected as ccd Wrong 1
With both: Speaker ccd094 Detected as ccd Wrong 1

With cepstrum: Speaker cch140 Detected as cch Wrong 1
With delta: Speaker cch140 Detected as cch Wrong 1
With both: Speaker cch140 Detected as cch Wrong 1

With cepstrum: Speaker cch142 Detected as cch Wrong 1
With delta: Speaker cch142 Detected as cch Wrong 1
With both: Speaker cch142 Detected as cch Wrong 1

With cepstrum: Speaker cch149 Detected as cch Wrong 1
With delta: Speaker cch149 Detected as cch Wrong 1
With both: Speaker cch149 Detected as cch Wrong 1

With cepstrum: Speaker ccv035 Detected as ccv Wrong 1
With delta: Speaker ccv035 Detected as cdn Wrong 2
With both: Speaker ccv035 Detected as ccv Wrong 1

With cepstrum: Speaker ccv039 Detected as ccv Wrong 1
With delta: Speaker ccv039 Detected as ccv Wrong 2
With both: Speaker ccv039 Detected as ccv Wrong 1

With cepstrum: Speaker ccv050 Detected as cgx Wrong 2
With delta: Speaker ccv050 Detected as cfs Wrong 3
With both: Speaker ccv050 Detected as ccv Wrong 1

With cepstrum: Speaker ccv052 Detected as ccv Wrong 2
With delta: Speaker ccv052 Detected as chn Wrong 4
With both: Speaker ccv052 Detected as ccv Wrong 1

With cepstrum: Speaker ccz041 Detected as ccz Wrong 2
With delta: Speaker ccz041 Detected as ccz Wrong 4
With both: Speaker ccz041 Detected as ccz Wrong 1

With cepstrum: Speaker ccz043 Detected as ccz Wrong 2
With delta: Speaker ccz043 Detected as ccz Wrong 4
With both: Speaker ccz043 Detected as ccz Wrong 1

With cepstrum: Speaker cdi009 Detected as cdi Wrong 2
With delta: Speaker cdi009 Detected as cdi Wrong 4
With both: Speaker cdi009 Detected as cdi Wrong 1

With cepstrum: Speaker cdi012 Detected as cdi Wrong 2
With delta: Speaker cdi012 Detected as cdi Wrong 4
With both: Speaker cdi012 Detected as cdi Wrong 1

With cepstrum: Speaker cdi022 Detected as cgx Wrong 3
With delta: Speaker cdi022 Detected as cdi Wrong 4
```



```
With both: Speaker cdi022 Detected as cgx Wrong 2

With cepstrum: Speaker cdk061 Detected as cdk Wrong 3
With delta: Speaker cdk061 Detected as cdk Wrong 4
With both: Speaker cdk061 Detected as cdk Wrong 2

With cepstrum: Speaker cdk063 Detected as cdk Wrong 3
With delta: Speaker cdk063 Detected as chn Wrong 5
With both: Speaker cdk063 Detected as cdk Wrong 2

With cepstrum: Speaker cdk065 Detected as cdn Wrong 4
With delta: Speaker cdk065 Detected as cdk Wrong 5
With both: Speaker cdk065 Detected as cdk Wrong 2

With cepstrum: Speaker cdn105 Detected as cdn Wrong 4
With delta: Speaker cdn105 Detected as cdn Wrong 5
With both: Speaker cdn105 Detected as cdn Wrong 2

With cepstrum: Speaker cdn107 Detected as cdn Wrong 4
With delta: Speaker cdn107 Detected as cdn Wrong 5
With both: Speaker cdn107 Detected as cdn Wrong 2

With cepstrum: Speaker cdn122 Detected as cdn Wrong 4
With delta: Speaker cdn122 Detected as cdn Wrong 5
With both: Speaker cdn122 Detected as cdn Wrong 2

With cepstrum: Speaker cdn126 Detected as cdn Wrong 4
With delta: Speaker cdn126 Detected as cdn Wrong 5
With both: Speaker cdn126 Detected as cdn Wrong 2

With cepstrum: Speaker cdn135 Detected as cdn Wrong 4
With delta: Speaker cdn135 Detected as cdn Wrong 5
With both: Speaker cdn135 Detected as cdn Wrong 2

With cepstrum: Speaker cdn139 Detected as cdn Wrong 4
With delta: Speaker cdn139 Detected as cdn Wrong 5
With both: Speaker cdn139 Detected as cdn Wrong 2

With cepstrum: Speaker cdt183 Detected as cdt Wrong 4
With delta: Speaker cdt183 Detected as cdt Wrong 5
With both: Speaker cdt183 Detected as cdt Wrong 2

With cepstrum: Speaker cdt187 Detected as cdt Wrong 4
With delta: Speaker cdt187 Detected as chn Wrong 6
With both: Speaker cdt187 Detected as cdt Wrong 2

With cepstrum: Speaker cdt198 Detected as cdt Wrong 4
With delta: Speaker cdt198 Detected as cel Wrong 7
With both: Speaker cdt198 Detected as cdt Wrong 2

With cepstrum: Speaker cdt237 Detected as cdt Wrong 4
With delta: Speaker cdt237 Detected as chn Wrong 8
With both: Speaker cdt237 Detected as cdt Wrong 2

With cepstrum: Speaker cdv078 Detected as cdv Wrong 4
With delta: Speaker cdv078 Detected as cgx Wrong 9
With both: Speaker cdv078 Detected as cdv Wrong 2
```

With cepstrum: Speaker cdv080 Detected as cdv Wrong 4
With delta: Speaker cdv080 Detected as ceb Wrong 10
With both: Speaker cdv080 Detected as cdv Wrong 2

With cepstrum: Speaker cdv081 Detected as cdv Wrong 4
With delta: Speaker cdv081 Detected as cii Wrong 11
With both: Speaker cdv081 Detected as cdk Wrong 3

With cepstrum: Speaker cdv095 Detected as cdv Wrong 4
With delta: Speaker cdv095 Detected as cgy Wrong 12
With both: Speaker cdv095 Detected as cdv Wrong 3

With cepstrum: Speaker cdw131 Detected as cdw Wrong 4
With delta: Speaker cdw131 Detected as cdv Wrong 13
With both: Speaker cdw131 Detected as cdw Wrong 3

With cepstrum: Speaker cdw142 Detected as cdw Wrong 4
With delta: Speaker cdw142 Detected as cdw Wrong 13
With both: Speaker cdw142 Detected as cdw Wrong 3

With cepstrum: Speaker cdw145 Detected as cdw Wrong 4
With delta: Speaker cdw145 Detected as cdw Wrong 13
With both: Speaker cdw145 Detected as cdw Wrong 3

With cepstrum: Speaker ceb014 Detected as ceb Wrong 4
With delta: Speaker ceb014 Detected as chn Wrong 14
With both: Speaker ceb014 Detected as ceb Wrong 3

With cepstrum: Speaker ceb015 Detected as ceb Wrong 4
With delta: Speaker ceb015 Detected as ceb Wrong 14
With both: Speaker ceb015 Detected as ceb Wrong 3

With cepstrum: Speaker ceb022 Detected as cin Wrong 5
With delta: Speaker ceb022 Detected as cgx Wrong 15
With both: Speaker ceb022 Detected as cin Wrong 4

With cepstrum: Speaker cel188 Detected as cel Wrong 5
With delta: Speaker cel188 Detected as cel Wrong 15
With both: Speaker cel188 Detected as cel Wrong 4

With cepstrum: Speaker cel190 Detected as cel Wrong 5
With delta: Speaker cel190 Detected as chn Wrong 16
With both: Speaker cel190 Detected as cel Wrong 4

With cepstrum: Speaker cel192 Detected as cel Wrong 5
With delta: Speaker cel192 Detected as cel Wrong 16
With both: Speaker cel192 Detected as cel Wrong 4

With cepstrum: Speaker cel202 Detected as cel Wrong 5
With delta: Speaker cel202 Detected as cin Wrong 17
With both: Speaker cel202 Detected as cel Wrong 4

With cepstrum: Speaker cel220 Detected as cel Wrong 5
With delta: Speaker cel220 Detected as cgy Wrong 18
With both: Speaker cel220 Detected as cel Wrong 4

With cepstrum: Speaker cem128 Detected as chj Wrong 6
With delta: Speaker cem128 Detected as chn Wrong 19

With both: Speaker cem128 Detected as chj Wrong 5

With cepstrum: Speaker cem131 Detected as cel Wrong 7
With delta: Speaker cem131 Detected as cfs Wrong 20
With both: Speaker cem131 Detected as cel Wrong 6

With cepstrum: Speaker cem137 Detected as chj Wrong 8
With delta: Speaker cem137 Detected as chn Wrong 21
With both: Speaker cem137 Detected as chj Wrong 7

With cepstrum: Speaker cev090 Detected as cev Wrong 8
With delta: Speaker cev090 Detected as cev Wrong 21
With both: Speaker cev090 Detected as cev Wrong 7

With cepstrum: Speaker cev092 Detected as cev Wrong 8
With delta: Speaker cev092 Detected as cev Wrong 21
With both: Speaker cev092 Detected as cev Wrong 7

With cepstrum: Speaker cev094 Detected as cev Wrong 8
With delta: Speaker cev094 Detected as cev Wrong 21
With both: Speaker cev094 Detected as cev Wrong 7

With cepstrum: Speaker cev101 Detected as cev Wrong 8
With delta: Speaker cev101 Detected as cev Wrong 21
With both: Speaker cev101 Detected as cev Wrong 7

With cepstrum: Speaker cev112 Detected as cev Wrong 8
With delta: Speaker cev112 Detected as cev Wrong 21
With both: Speaker cev112 Detected as cev Wrong 7

With cepstrum: Speaker cfi013 Detected as cfi Wrong 8
With delta: Speaker cfi013 Detected as cfi Wrong 21
With both: Speaker cfi013 Detected as cfi Wrong 7

With cepstrum: Speaker cfi018 Detected as cfi Wrong 8
With delta: Speaker cfi018 Detected as cfi Wrong 21
With both: Speaker cfi018 Detected as cfi Wrong 7

With cepstrum: Speaker cfi020 Detected as cfi Wrong 8
With delta: Speaker cfi020 Detected as cfi Wrong 21
With both: Speaker cfi020 Detected as cfi Wrong 7

With cepstrum: Speaker cfi021 Detected as cfi Wrong 8
With delta: Speaker cfi021 Detected as cfi Wrong 21
With both: Speaker cfi021 Detected as cfi Wrong 7

With cepstrum: Speaker cfi024 Detected as cfi Wrong 8
With delta: Speaker cfi024 Detected as cfi Wrong 21
With both: Speaker cfi024 Detected as cfi Wrong 7

With cepstrum: Speaker cfj054 Detected as cfj Wrong 8
With delta: Speaker cfj054 Detected as cdi Wrong 22
With both: Speaker cfj054 Detected as cfj Wrong 7

With cepstrum: Speaker cfj055 Detected as cfj Wrong 8
With delta: Speaker cfj055 Detected as cfj Wrong 22
With both: Speaker cfj055 Detected as cfj Wrong 7

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With cepstrum: Speaker cfj056 Detected as cfj Wrong 8
With delta: Speaker cfj056 Detected as cdn Wrong 23
With both: Speaker cfj056 Detected as cfj Wrong 7

With cepstrum: Speaker cfj057 Detected as cfj Wrong 8
With delta: Speaker cfj057 Detected as cfj Wrong 23
With both: Speaker cfj057 Detected as cfj Wrong 7

With cepstrum: Speaker cfp027 Detected as cfp Wrong 8
With delta: Speaker cfp027 Detected as cfp Wrong 23
With both: Speaker cfp027 Detected as cfp Wrong 7

With cepstrum: Speaker cfp043 Detected as cfp Wrong 8
With delta: Speaker cfp043 Detected as cfp Wrong 23
With both: Speaker cfp043 Detected as cfp Wrong 7

With cepstrum: Speaker cfp048 Detected as cfp Wrong 8
With delta: Speaker cfp048 Detected as cfp Wrong 23
With both: Speaker cfp048 Detected as cfp Wrong 7

With cepstrum: Speaker cfp058 Detected as cfp Wrong 8
With delta: Speaker cfp058 Detected as cfp Wrong 23
With both: Speaker cfp058 Detected as cfp Wrong 7

With cepstrum: Speaker cfp061 Detected as cfp Wrong 8
With delta: Speaker cfp061 Detected as cfp Wrong 23
With both: Speaker cfp061 Detected as cfp Wrong 7

With cepstrum: Speaker cfs038 Detected as cfs Wrong 8
With delta: Speaker cfs038 Detected as cfs Wrong 23
With both: Speaker cfs038 Detected as cfs Wrong 7

With cepstrum: Speaker cfs041 Detected as cfs Wrong 8
With delta: Speaker cfs041 Detected as cfs Wrong 23
With both: Speaker cfs041 Detected as cfs Wrong 7

With cepstrum: Speaker cfs045 Detected as cfs Wrong 8
With delta: Speaker cfs045 Detected as cfs Wrong 23
With both: Speaker cfs045 Detected as cfs Wrong 7

With cepstrum: Speaker cfu025 Detected as cfu Wrong 8
With delta: Speaker cfu025 Detected as cgx Wrong 24
With both: Speaker cfu025 Detected as cfu Wrong 7

With cepstrum: Speaker cfu034 Detected as cfu Wrong 8
With delta: Speaker cfu034 Detected as cfu Wrong 24
With both: Speaker cfu034 Detected as cfu Wrong 7

With cepstrum: Speaker cfu043 Detected as cfu Wrong 8
With delta: Speaker cfu043 Detected as cfu Wrong 24
With both: Speaker cfu043 Detected as cfu Wrong 7

With cepstrum: Speaker cfu071 Detected as cfu Wrong 8
With delta: Speaker cfu071 Detected as cii Wrong 25
With both: Speaker cfu071 Detected as cfu Wrong 7

With cepstrum: Speaker cfu075 Detected as cfu Wrong 8
With delta: Speaker cfu075 Detected as ceb Wrong 26
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With both: Speaker cfu075 Detected as cfu Wrong 7

With cepstrum: Speaker cfu079 Detected as cfu Wrong 8
With delta: Speaker cfu079 Detected as cgy Wrong 27
With both: Speaker cfu079 Detected as cfu Wrong 7

With cepstrum: Speaker cfu089 Detected as cfu Wrong 8
With delta: Speaker cfu089 Detected as cfu Wrong 27
With both: Speaker cfu089 Detected as cfu Wrong 7

With cepstrum: Speaker cfu095 Detected as cfu Wrong 8
With delta: Speaker cfu095 Detected as cfu Wrong 27
With both: Speaker cfu095 Detected as cfu Wrong 7

With cepstrum: Speaker cfu099 Detected as cfu Wrong 8
With delta: Speaker cfu099 Detected as cgy Wrong 28
With both: Speaker cfu099 Detected as cfu Wrong 7

With cepstrum: Speaker cfu109 Detected as cfu Wrong 8
With delta: Speaker cfu109 Detected as cfu Wrong 28
With both: Speaker cfu109 Detected as cfu Wrong 7

With cepstrum: Speaker cfu112 Detected as cfu Wrong 8
With delta: Speaker cfu112 Detected as cfu Wrong 28
With both: Speaker cfu112 Detected as cfu Wrong 7

With cepstrum: Speaker cfu116 Detected as cfu Wrong 8
With delta: Speaker cfu116 Detected as cgy Wrong 29
With both: Speaker cfu116 Detected as cfu Wrong 7

With cepstrum: Speaker cfx080 Detected as cfx Wrong 8
With delta: Speaker cfx080 Detected as cfx Wrong 29
With both: Speaker cfx080 Detected as cfx Wrong 7

With cepstrum: Speaker cfx088 Detected as cfx Wrong 8
With delta: Speaker cfx088 Detected as cdn Wrong 30
With both: Speaker cfx088 Detected as cfx Wrong 7

With cepstrum: Speaker cfx094 Detected as cfx Wrong 8
With delta: Speaker cfx094 Detected as cdn Wrong 31
With both: Speaker cfx094 Detected as cfx Wrong 7

With cepstrum: Speaker cga092 Detected as cga Wrong 8
With delta: Speaker cga092 Detected as cga Wrong 31
With both: Speaker cga092 Detected as cga Wrong 7

With cepstrum: Speaker cga098 Detected as cga Wrong 8
With delta: Speaker cga098 Detected as cga Wrong 31
With both: Speaker cga098 Detected as cga Wrong 7

With cepstrum: Speaker cga100 Detected as cga Wrong 8
With delta: Speaker cga100 Detected as cga Wrong 31
With both: Speaker cga100 Detected as cga Wrong 7

With cepstrum: Speaker cga104 Detected as cga Wrong 8
With delta: Speaker cga104 Detected as cga Wrong 31
With both: Speaker cga104 Detected as cga Wrong 7
```

```
With cepstrum: Speaker cge113 Detected as cge Wrong 8
With delta: Speaker cge113 Detected as cge Wrong 31
With both: Speaker cge113 Detected as cge Wrong 7

With cepstrum: Speaker cge117 Detected as cge Wrong 8
With delta: Speaker cge117 Detected as cge Wrong 31
With both: Speaker cge117 Detected as cge Wrong 7

With cepstrum: Speaker cge120 Detected as cge Wrong 8
With delta: Speaker cge120 Detected as cge Wrong 31
With both: Speaker cge120 Detected as cge Wrong 7

With cepstrum: Speaker cge122 Detected as cge Wrong 8
With delta: Speaker cge122 Detected as cge Wrong 31
With both: Speaker cge122 Detected as cge Wrong 7

With cepstrum: Speaker cgm168 Detected as cgm Wrong 8
With delta: Speaker cgm168 Detected as cgm Wrong 31
With both: Speaker cgm168 Detected as cgm Wrong 7

With cepstrum: Speaker cgp007 Detected as cgp Wrong 8
With delta: Speaker cgp007 Detected as chn Wrong 32
With both: Speaker cgp007 Detected as cgp Wrong 7

With cepstrum: Speaker cgp138 Detected as cgp Wrong 8
With delta: Speaker cgp138 Detected as cfx Wrong 33
With both: Speaker cgp138 Detected as cgp Wrong 7

With cepstrum: Speaker cgp143 Detected as cgp Wrong 8
With delta: Speaker cgp143 Detected as cdi Wrong 34
With both: Speaker cgp143 Detected as cgp Wrong 7

With cepstrum: Speaker cgp152 Detected as cgp Wrong 8
With delta: Speaker cgp152 Detected as cgy Wrong 35
With both: Speaker cgp152 Detected as cgp Wrong 7

With cepstrum: Speaker cgp176 Detected as cdk Wrong 9
With delta: Speaker cgp176 Detected as cfs Wrong 36
With both: Speaker cgp176 Detected as cdn Wrong 8

With cepstrum: Speaker cgx079 Detected as cgx Wrong 9
With delta: Speaker cgx079 Detected as cgx Wrong 36
With both: Speaker cgx079 Detected as cgx Wrong 8

With cepstrum: Speaker cgx081 Detected as cgx Wrong 9
With delta: Speaker cgx081 Detected as cgx Wrong 36
With both: Speaker cgx081 Detected as cgx Wrong 8

With cepstrum: Speaker cgx096 Detected as cgx Wrong 9
With delta: Speaker cgx096 Detected as cel Wrong 37
With both: Speaker cgx096 Detected as cgx Wrong 8

With cepstrum: Speaker cgy117 Detected as cgy Wrong 9
With delta: Speaker cgy117 Detected as cgy Wrong 37
With both: Speaker cgy117 Detected as cgy Wrong 8

With cepstrum: Speaker chc098 Detected as chc Wrong 9
With delta: Speaker chc098 Detected as chc Wrong 37
```



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With both: Speaker chc098 Detected as chc Wrong 8

With cepstrum: Speaker chg124 Detected as chg Wrong 9
With delta: Speaker chg124 Detected as ccz Wrong 38
With both: Speaker chg124 Detected as chg Wrong 8

With cepstrum: Speaker chg126 Detected as chg Wrong 9
With delta: Speaker chg126 Detected as chg Wrong 38
With both: Speaker chg126 Detected as chg Wrong 8

With cepstrum: Speaker chg173 Detected as chg Wrong 9
With delta: Speaker chg173 Detected as chg Wrong 38
With both: Speaker chg173 Detected as chg Wrong 8

With cepstrum: Speaker chg176 Detected as chg Wrong 9
With delta: Speaker chg176 Detected as chg Wrong 38
With both: Speaker chg176 Detected as chg Wrong 8

With cepstrum: Speaker chg187 Detected as chg Wrong 9
With delta: Speaker chg187 Detected as chg Wrong 38
With both: Speaker chg187 Detected as chg Wrong 8

With cepstrum: Speaker chg197 Detected as chg Wrong 9
With delta: Speaker chg197 Detected as chg Wrong 38
With both: Speaker chg197 Detected as chg Wrong 8

With cepstrum: Speaker chg203 Detected as chg Wrong 9
With delta: Speaker chg203 Detected as chg Wrong 38
With both: Speaker chg203 Detected as chg Wrong 8

With cepstrum: Speaker chg209 Detected as cdk Wrong 10
With delta: Speaker chg209 Detected as chg Wrong 38
With both: Speaker chg209 Detected as chg Wrong 8

With cepstrum: Speaker chj037 Detected as chj Wrong 10
With delta: Speaker chj037 Detected as chj Wrong 38
With both: Speaker chj037 Detected as chj Wrong 8

With cepstrum: Speaker chj039 Detected as chj Wrong 10
With delta: Speaker chj039 Detected as chn Wrong 39
With both: Speaker chj039 Detected as chj Wrong 8

With cepstrum: Speaker chj043 Detected as chj Wrong 10
With delta: Speaker chj043 Detected as chj Wrong 39
With both: Speaker chj043 Detected as chj Wrong 8

With cepstrum: Speaker chj044 Detected as chj Wrong 10
With delta: Speaker chj044 Detected as chj Wrong 39
With both: Speaker chj044 Detected as chj Wrong 8

With cepstrum: Speaker chj052 Detected as chj Wrong 10
With delta: Speaker chj052 Detected as chj Wrong 39
With both: Speaker chj052 Detected as chj Wrong 8

With cepstrum: Speaker chj206 Detected as chj Wrong 10
With delta: Speaker chj206 Detected as cgy Wrong 40
With both: Speaker chj206 Detected as chj Wrong 8
```

With cepstrum: Speaker chj210 Detected as chj Wrong 10
With delta: Speaker chj210 Detected as chj Wrong 40
With both: Speaker chj210 Detected as chj Wrong 8

With cepstrum: Speaker chj212 Detected as chj Wrong 10
With delta: Speaker chj212 Detected as chj Wrong 40
With both: Speaker chj212 Detected as chj Wrong 8

With cepstrum: Speaker chj232 Detected as chj Wrong 10
With delta: Speaker chj232 Detected as chj Wrong 40
With both: Speaker chj232 Detected as chj Wrong 8

With cepstrum: Speaker chj241 Detected as chj Wrong 10
With delta: Speaker chj241 Detected as chj Wrong 40
With both: Speaker chj241 Detected as chj Wrong 8

With cepstrum: Speaker chn110 Detected as chn Wrong 10
With delta: Speaker chn110 Detected as chn Wrong 40
With both: Speaker chn110 Detected as chn Wrong 8

With cepstrum: Speaker chn116 Detected as chn Wrong 10
With delta: Speaker chn116 Detected as chn Wrong 40
With both: Speaker chn116 Detected as chn Wrong 8

With cepstrum: Speaker chn118 Detected as chn Wrong 10
With delta: Speaker chn118 Detected as cii Wrong 41
With both: Speaker chn118 Detected as chn Wrong 8

With cepstrum: Speaker chs072 Detected as chs Wrong 10
With delta: Speaker chs072 Detected as chg Wrong 42
With both: Speaker chs072 Detected as chs Wrong 8

With cepstrum: Speaker chs095 Detected as chs Wrong 10
With delta: Speaker chs095 Detected as chs Wrong 42
With both: Speaker chs095 Detected as chs Wrong 8

With cepstrum: Speaker chs096 Detected as chs Wrong 10
With delta: Speaker chs096 Detected as chy Wrong 43
With both: Speaker chs096 Detected as chs Wrong 8

With cepstrum: Speaker chs109 Detected as chy Wrong 11
With delta: Speaker chs109 Detected as chs Wrong 43
With both: Speaker chs109 Detected as chy Wrong 9

With cepstrum: Speaker chy130 Detected as chy Wrong 11
With delta: Speaker chy130 Detected as chn Wrong 44
With both: Speaker chy130 Detected as chy Wrong 9

With cepstrum: Speaker cic140 Detected as cic Wrong 11
With delta: Speaker cic140 Detected as cic Wrong 44
With both: Speaker cic140 Detected as cic Wrong 9

With cepstrum: Speaker cic142 Detected as cic Wrong 11
With delta: Speaker cic142 Detected as cic Wrong 44
With both: Speaker cic142 Detected as cic Wrong 9

With cepstrum: Speaker cic146 Detected as cic Wrong 11
With delta: Speaker cic146 Detected as chn Wrong 45

With both: Speaker cic146 Detected as cic Wrong 9

With cepstrum: Speaker cif074 Detected as cif Wrong 11
With delta: Speaker cif074 Detected as cif Wrong 45
With both: Speaker cif074 Detected as cif Wrong 9

With cepstrum: Speaker cif076 Detected as cif Wrong 11
With delta: Speaker cif076 Detected as chn Wrong 46
With both: Speaker cif076 Detected as cif Wrong 9

With cepstrum: Speaker cif078 Detected as cif Wrong 11
With delta: Speaker cif078 Detected as cif Wrong 46
With both: Speaker cif078 Detected as cif Wrong 9

With cepstrum: Speaker cif088 Detected as cif Wrong 11
With delta: Speaker cif088 Detected as cif Wrong 46
With both: Speaker cif088 Detected as cif Wrong 9

With cepstrum: Speaker cif100 Detected as cif Wrong 11
With delta: Speaker cif100 Detected as cif Wrong 46
With both: Speaker cif100 Detected as cif Wrong 9

With cepstrum: Speaker cii102 Detected as cii Wrong 11
With delta: Speaker cii102 Detected as cgx Wrong 47
With both: Speaker cii102 Detected as cii Wrong 9

With cepstrum: Speaker cii104 Detected as cii Wrong 11
With delta: Speaker cii104 Detected as cii Wrong 47
With both: Speaker cii104 Detected as cii Wrong 9

With cepstrum: Speaker cii109 Detected as cii Wrong 11
With delta: Speaker cii109 Detected as chn Wrong 48
With both: Speaker cii109 Detected as cii Wrong 9

With cepstrum: Speaker cik182 Detected as chj Wrong 12
With delta: Speaker cik182 Detected as cgy Wrong 49
With both: Speaker cik182 Detected as cik Wrong 9

With cepstrum: Speaker cik193 Detected as cik Wrong 12
With delta: Speaker cik193 Detected as cik Wrong 49
With both: Speaker cik193 Detected as cik Wrong 9

With cepstrum: Speaker cik195 Detected as cik Wrong 12
With delta: Speaker cik195 Detected as chc Wrong 50
With both: Speaker cik195 Detected as chc Wrong 10

With cepstrum: Speaker cin013 Detected as cin Wrong 12
With delta: Speaker cin013 Detected as cfp Wrong 51
With both: Speaker cin013 Detected as cin Wrong 10

With cepstrum: Speaker cin023 Detected as cin Wrong 12
With delta: Speaker cin023 Detected as cin Wrong 51
With both: Speaker cin023 Detected as cin Wrong 10

With cepstrum: Speaker cjl055 Detected as cjl Wrong 12
With delta: Speaker cjl055 Detected as cjl Wrong 51
With both: Speaker cjl055 Detected as cjl Wrong 10

```
With cepstrum: Speaker cjl060 Detected as cjl Wrong 12
With delta: Speaker cjl060 Detected as cjl Wrong 51
With both: Speaker cjl060 Detected as cjl Wrong 10

With cepstrum: Speaker ckb053 Detected as ckb Wrong 12
With delta: Speaker ckb053 Detected as ckb Wrong 51
With both: Speaker ckb053 Detected as ckb Wrong 10

With cepstrum: Speaker ckb062 Detected as ckb Wrong 12
With delta: Speaker ckb062 Detected as ckb Wrong 51
With both: Speaker ckb062 Detected as ckb Wrong 10

With cepstrum: Speaker ckb066 Detected as ckb Wrong 12
With delta: Speaker ckb066 Detected as ckb Wrong 51
With both: Speaker ckb066 Detected as ckb Wrong 10

With cepstrum: Speaker ckb071 Detected as cel Wrong 13
With delta: Speaker ckb071 Detected as cdi Wrong 52
With both: Speaker ckb071 Detected as ckb Wrong 10

With cepstrum: Speaker ckb074 Detected as ckb Wrong 13
With delta: Speaker ckb074 Detected as ckb Wrong 52
With both: Speaker ckb074 Detected as ckb Wrong 10

With cepstrum: Speaker ckb078 Detected as ckb Wrong 13
With delta: Speaker ckb078 Detected as ckb Wrong 52
With both: Speaker ckb078 Detected as ckb Wrong 10

With cepstrum: Speaker ckc058 Detected as ckc Wrong 13
With delta: Speaker ckc058 Detected as ckc Wrong 52
With both: Speaker ckc058 Detected as ckc Wrong 10

With cepstrum: Speaker ckc067 Detected as ckc Wrong 13
With delta: Speaker ckc067 Detected as ckc Wrong 52
With both: Speaker ckc067 Detected as ckc Wrong 10

With cepstrum: Speaker ckc069 Detected as ckc Wrong 13
With delta: Speaker ckc069 Detected as ckc Wrong 52
With both: Speaker ckc069 Detected as ckc Wrong 10

With cepstrum: Speaker ckc077 Detected as ckc Wrong 13
With delta: Speaker ckc077 Detected as ckc Wrong 52
With both: Speaker ckc077 Detected as ckc Wrong 10

With cepstrum: Speaker ckd088 Detected as ckd Wrong 13
With delta: Speaker ckd088 Detected as ckd Wrong 52
With both: Speaker ckd088 Detected as ckd Wrong 10

With cepstrum: Speaker ckd124 Detected as ckd Wrong 13
With delta: Speaker ckd124 Detected as cin Wrong 53
With both: Speaker ckd124 Detected as ckd Wrong 10

With cepstrum: Speaker ckd133 Detected as ckd Wrong 13
With delta: Speaker ckd133 Detected as ckd Wrong 53
With both: Speaker ckd133 Detected as ckd Wrong 10

percent correct cepstrum = 91.823899
percent correct delta cepstrum = 66.666667
```



```
percent correct both =93.710692
```

With Cepstrum and Acceleration Cepstrum

```
With cepstrum: Speaker ccd064 Detected as ccd Wrong 0
With acceleration: Speaker ccd064 Detected as cgy Wrong 1
With both: Speaker ccd064 Detected as ccd Wrong 0

With cepstrum: Speaker ccd078 Detected as cdn Wrong 1
With acceleration: Speaker ccd078 Detected as ccz Wrong 2
With both: Speaker ccd078 Detected as ccz Wrong 1

With cepstrum: Speaker ccd094 Detected as ccd Wrong 1
With acceleration: Speaker ccd094 Detected as chn Wrong 3
With both: Speaker ccd094 Detected as ccd Wrong 1

With cepstrum: Speaker cch140 Detected as cch Wrong 1
With acceleration: Speaker cch140 Detected as chn Wrong 4
With both: Speaker cch140 Detected as cch Wrong 1

With cepstrum: Speaker cch142 Detected as cch Wrong 1
With acceleration: Speaker cch142 Detected as cfs Wrong 5
With both: Speaker cch142 Detected as cch Wrong 1

With cepstrum: Speaker cch149 Detected as cch Wrong 1
With acceleration: Speaker cch149 Detected as chn Wrong 6
With both: Speaker cch149 Detected as cch Wrong 1

With cepstrum: Speaker ccv035 Detected as ccv Wrong 1
With acceleration: Speaker ccv035 Detected as cfs Wrong 7
With both: Speaker ccv035 Detected as ccv Wrong 1

With cepstrum: Speaker ccv039 Detected as ccv Wrong 1
With acceleration: Speaker ccv039 Detected as ccv Wrong 7
With both: Speaker ccv039 Detected as ccv Wrong 1

With cepstrum: Speaker ccv050 Detected as cgx Wrong 2
With acceleration: Speaker ccv050 Detected as cfs Wrong 8
With both: Speaker ccv050 Detected as cii Wrong 2

With cepstrum: Speaker ccv052 Detected as ccv Wrong 2
With acceleration: Speaker ccv052 Detected as cfs Wrong 9
With both: Speaker ccv052 Detected as ccv Wrong 2

With cepstrum: Speaker ccz041 Detected as ccz Wrong 2
With acceleration: Speaker ccz041 Detected as chn Wrong 10
With both: Speaker ccz041 Detected as ccz Wrong 2

With cepstrum: Speaker ccz043 Detected as ccz Wrong 2
With acceleration: Speaker ccz043 Detected as chc Wrong 11
With both: Speaker ccz043 Detected as ccz Wrong 2

With cepstrum: Speaker cdi009 Detected as cdi Wrong 2
With acceleration: Speaker cdi009 Detected as cdi Wrong 11
With both: Speaker cdi009 Detected as cdi Wrong 2

With cepstrum: Speaker cdi012 Detected as cdi Wrong 2
With acceleration: Speaker cdi012 Detected as chn Wrong 12
With both: Speaker cdi012 Detected as cdi Wrong 2

With cepstrum: Speaker cdi022 Detected as cgx Wrong 3
With acceleration: Speaker cdi022 Detected as chn Wrong 13
```



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With both: Speaker cdi022 Detected as cgx Wrong 3

With cepstrum: Speaker cdk061 Detected as cdk Wrong 3
With acceleration: Speaker cdk061 Detected as cdk Wrong 13
With both: Speaker cdk061 Detected as cdk Wrong 3

With cepstrum: Speaker cdk063 Detected as cdk Wrong 3
With acceleration: Speaker cdk063 Detected as chn Wrong 14
With both: Speaker cdk063 Detected as cdk Wrong 3

With cepstrum: Speaker cdk065 Detected as cdn Wrong 4
With acceleration: Speaker cdk065 Detected as ceb Wrong 15
With both: Speaker cdk065 Detected as cdn Wrong 4

With cepstrum: Speaker cdn105 Detected as cdn Wrong 4
With acceleration: Speaker cdn105 Detected as cdn Wrong 15
With both: Speaker cdn105 Detected as cdn Wrong 4

With cepstrum: Speaker cdn107 Detected as cdn Wrong 4
With acceleration: Speaker cdn107 Detected as cdn Wrong 15
With both: Speaker cdn107 Detected as cdn Wrong 4

With cepstrum: Speaker cdn122 Detected as cdn Wrong 4
With acceleration: Speaker cdn122 Detected as cdn Wrong 15
With both: Speaker cdn122 Detected as cdn Wrong 4

With cepstrum: Speaker cdn126 Detected as cdn Wrong 4
With acceleration: Speaker cdn126 Detected as cgy Wrong 16
With both: Speaker cdn126 Detected as cdn Wrong 4

With cepstrum: Speaker cdn135 Detected as cdn Wrong 4
With acceleration: Speaker cdn135 Detected as chn Wrong 17
With both: Speaker cdn135 Detected as cdn Wrong 4

With cepstrum: Speaker cdn139 Detected as cdn Wrong 4
With acceleration: Speaker cdn139 Detected as chn Wrong 18
With both: Speaker cdn139 Detected as cdn Wrong 4

With cepstrum: Speaker cdt183 Detected as cdt Wrong 4
With acceleration: Speaker cdt183 Detected as chn Wrong 19
With both: Speaker cdt183 Detected as cdt Wrong 4

With cepstrum: Speaker cdt187 Detected as cdt Wrong 4
With acceleration: Speaker cdt187 Detected as chn Wrong 20
With both: Speaker cdt187 Detected as cdt Wrong 4

With cepstrum: Speaker cdt198 Detected as cdt Wrong 4
With acceleration: Speaker cdt198 Detected as chn Wrong 21
With both: Speaker cdt198 Detected as cdt Wrong 4

With cepstrum: Speaker cdt237 Detected as cdt Wrong 4
With acceleration: Speaker cdt237 Detected as chn Wrong 22
With both: Speaker cdt237 Detected as cdt Wrong 4

With cepstrum: Speaker cdv078 Detected as cdv Wrong 4
With acceleration: Speaker cdv078 Detected as cdv Wrong 22
With both: Speaker cdv078 Detected as cdv Wrong 4
```

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With cepstrum: Speaker cdv080 Detected as cdv Wrong 4
With acceleration: Speaker cdv080 Detected as cdv Wrong 22
With both: Speaker cdv080 Detected as cdv Wrong 4

With cepstrum: Speaker cdv081 Detected as cdv Wrong 4
With acceleration: Speaker cdv081 Detected as chn Wrong 23
With both: Speaker cdv081 Detected as cdk Wrong 5

With cepstrum: Speaker cdv095 Detected as cdv Wrong 4
With acceleration: Speaker cdv095 Detected as chn Wrong 24
With both: Speaker cdv095 Detected as cii Wrong 6

With cepstrum: Speaker cdw131 Detected as cdw Wrong 4
With acceleration: Speaker cdw131 Detected as ccz Wrong 25
With both: Speaker cdw131 Detected as cdw Wrong 6

With cepstrum: Speaker cdw142 Detected as cdw Wrong 4
With acceleration: Speaker cdw142 Detected as chn Wrong 26
With both: Speaker cdw142 Detected as cdw Wrong 6

With cepstrum: Speaker cdw145 Detected as cdw Wrong 4
With acceleration: Speaker cdw145 Detected as chn Wrong 27
With both: Speaker cdw145 Detected as cdw Wrong 6

With cepstrum: Speaker ceb014 Detected as ceb Wrong 4
With acceleration: Speaker ceb014 Detected as chn Wrong 28
With both: Speaker ceb014 Detected as ceb Wrong 6

With cepstrum: Speaker ceb015 Detected as ceb Wrong 4
With acceleration: Speaker ceb015 Detected as chn Wrong 29
With both: Speaker ceb015 Detected as ceb Wrong 6

With cepstrum: Speaker ceb022 Detected as cin Wrong 5
With acceleration: Speaker ceb022 Detected as chn Wrong 30
With both: Speaker ceb022 Detected as cin Wrong 7

With cepstrum: Speaker cel188 Detected as cel Wrong 5
With acceleration: Speaker cel188 Detected as cel Wrong 30
With both: Speaker cel188 Detected as cel Wrong 7

With cepstrum: Speaker cel190 Detected as cel Wrong 5
With acceleration: Speaker cel190 Detected as chn Wrong 31
With both: Speaker cel190 Detected as cel Wrong 7

With cepstrum: Speaker cel192 Detected as cel Wrong 5
With acceleration: Speaker cel192 Detected as chn Wrong 32
With both: Speaker cel192 Detected as cel Wrong 7

With cepstrum: Speaker cel202 Detected as cel Wrong 5
With acceleration: Speaker cel202 Detected as cgy Wrong 33
With both: Speaker cel202 Detected as cel Wrong 7

With cepstrum: Speaker cel220 Detected as cel Wrong 5
With acceleration: Speaker cel220 Detected as ckb Wrong 34
With both: Speaker cel220 Detected as cel Wrong 7

With cepstrum: Speaker cem128 Detected as chj Wrong 6
With acceleration: Speaker cem128 Detected as chn Wrong 35
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With both: Speaker cem128 Detected as chj Wrong 8

With cepstrum: Speaker cem131 Detected as cel Wrong 7
With acceleration: Speaker cem131 Detected as chj Wrong 36
With both: Speaker cem131 Detected as cel Wrong 9

With cepstrum: Speaker cem137 Detected as chj Wrong 8
With acceleration: Speaker cem137 Detected as chn Wrong 37
With both: Speaker cem137 Detected as chj Wrong 10

With cepstrum: Speaker cev090 Detected as cev Wrong 8
With acceleration: Speaker cev090 Detected as cic Wrong 38
With both: Speaker cev090 Detected as cev Wrong 10

With cepstrum: Speaker cev092 Detected as cev Wrong 8
With acceleration: Speaker cev092 Detected as cic Wrong 39
With both: Speaker cev092 Detected as cev Wrong 10

With cepstrum: Speaker cev094 Detected as cev Wrong 8
With acceleration: Speaker cev094 Detected as chn Wrong 40
With both: Speaker cev094 Detected as cev Wrong 10

With cepstrum: Speaker cev101 Detected as cev Wrong 8
With acceleration: Speaker cev101 Detected as chn Wrong 41
With both: Speaker cev101 Detected as cev Wrong 10

With cepstrum: Speaker cev112 Detected as cev Wrong 8
With acceleration: Speaker cev112 Detected as cev Wrong 41
With both: Speaker cev112 Detected as cev Wrong 10

With cepstrum: Speaker cfi013 Detected as cfi Wrong 8
With acceleration: Speaker cfi013 Detected as cfi Wrong 41
With both: Speaker cfi013 Detected as cfi Wrong 10

With cepstrum: Speaker cfi018 Detected as cfi Wrong 8
With acceleration: Speaker cfi018 Detected as cgy Wrong 42
With both: Speaker cfi018 Detected as cfi Wrong 10

With cepstrum: Speaker cfi020 Detected as cfi Wrong 8
With acceleration: Speaker cfi020 Detected as cfi Wrong 42
With both: Speaker cfi020 Detected as cfi Wrong 10

With cepstrum: Speaker cfi021 Detected as cfi Wrong 8
With acceleration: Speaker cfi021 Detected as cfi Wrong 42
With both: Speaker cfi021 Detected as cfi Wrong 10

With cepstrum: Speaker cfi024 Detected as cfi Wrong 8
With acceleration: Speaker cfi024 Detected as cgy Wrong 43
With both: Speaker cfi024 Detected as cfi Wrong 10

With cepstrum: Speaker cfj054 Detected as cfj Wrong 8
With acceleration: Speaker cfj054 Detected as chn Wrong 44
With both: Speaker cfj054 Detected as cfj Wrong 10

With cepstrum: Speaker cfj055 Detected as cfj Wrong 8
With acceleration: Speaker cfj055 Detected as cgy Wrong 45
With both: Speaker cfj055 Detected as cfj Wrong 10
```

With cepstrum: Speaker cfj056 Detected as cfj Wrong 8
With acceleration: Speaker cfj056 Detected as chn Wrong 46
With both: Speaker cfj056 Detected as cfj Wrong 10

With cepstrum: Speaker cfj057 Detected as cfj Wrong 8
With acceleration: Speaker cfj057 Detected as cgy Wrong 47
With both: Speaker cfj057 Detected as cfj Wrong 10

With cepstrum: Speaker cfp027 Detected as cfp Wrong 8
With acceleration: Speaker cfp027 Detected as cfp Wrong 47
With both: Speaker cfp027 Detected as cfp Wrong 10

With cepstrum: Speaker cfp043 Detected as cfp Wrong 8
With acceleration: Speaker cfp043 Detected as cfp Wrong 47
With both: Speaker cfp043 Detected as cfp Wrong 10

With cepstrum: Speaker cfp048 Detected as cfp Wrong 8
With acceleration: Speaker cfp048 Detected as cfp Wrong 47
With both: Speaker cfp048 Detected as cfp Wrong 10

With cepstrum: Speaker cfp058 Detected as cfp Wrong 8
With acceleration: Speaker cfp058 Detected as cfs Wrong 48
With both: Speaker cfp058 Detected as cfp Wrong 10

With cepstrum: Speaker cfp061 Detected as cfp Wrong 8
With acceleration: Speaker cfp061 Detected as chn Wrong 49
With both: Speaker cfp061 Detected as cfp Wrong 10

With cepstrum: Speaker cfs038 Detected as cfs Wrong 8
With acceleration: Speaker cfs038 Detected as cfs Wrong 49
With both: Speaker cfs038 Detected as cfs Wrong 10

With cepstrum: Speaker cfs041 Detected as cfs Wrong 8
With acceleration: Speaker cfs041 Detected as cfs Wrong 49
With both: Speaker cfs041 Detected as cfs Wrong 10

With cepstrum: Speaker cfs045 Detected as cfs Wrong 8
With acceleration: Speaker cfs045 Detected as cfs Wrong 49
With both: Speaker cfs045 Detected as cfs Wrong 10

With cepstrum: Speaker cfu025 Detected as cfu Wrong 8
With acceleration: Speaker cfu025 Detected as cgy Wrong 50
With both: Speaker cfu025 Detected as cfu Wrong 10

With cepstrum: Speaker cfu034 Detected as cfu Wrong 8
With acceleration: Speaker cfu034 Detected as cgy Wrong 51
With both: Speaker cfu034 Detected as cfu Wrong 10

With cepstrum: Speaker cfu043 Detected as cfu Wrong 8
With acceleration: Speaker cfu043 Detected as cgy Wrong 52
With both: Speaker cfu043 Detected as cfu Wrong 10

With cepstrum: Speaker cfu071 Detected as cfu Wrong 8
With acceleration: Speaker cfu071 Detected as cii Wrong 53
With both: Speaker cfu071 Detected as cfu Wrong 10

With cepstrum: Speaker cfu075 Detected as cfu Wrong 8
With acceleration: Speaker cfu075 Detected as cfj Wrong 54

With both: Speaker cfu075 Detected as cfu Wrong 10

With cepstrum: Speaker cfu079 Detected as cfu Wrong 8
With acceleration: Speaker cfu079 Detected as cdi Wrong 55
With both: Speaker cfu079 Detected as cfu Wrong 10

With cepstrum: Speaker cfu089 Detected as cfu Wrong 8
With acceleration: Speaker cfu089 Detected as cii Wrong 56
With both: Speaker cfu089 Detected as cfu Wrong 10

With cepstrum: Speaker cfu095 Detected as cfu Wrong 8
With acceleration: Speaker cfu095 Detected as cii Wrong 57
With both: Speaker cfu095 Detected as cfu Wrong 10

With cepstrum: Speaker cfu099 Detected as cfu Wrong 8
With acceleration: Speaker cfu099 Detected as cfs Wrong 58
With both: Speaker cfu099 Detected as cfu Wrong 10

With cepstrum: Speaker cfu109 Detected as cfu Wrong 8
With acceleration: Speaker cfu109 Detected as cgy Wrong 59
With both: Speaker cfu109 Detected as cfu Wrong 10

With cepstrum: Speaker cfu112 Detected as cfu Wrong 8
With acceleration: Speaker cfu112 Detected as cgy Wrong 60
With both: Speaker cfu112 Detected as cfu Wrong 10

With cepstrum: Speaker cfu116 Detected as cfu Wrong 8
With acceleration: Speaker cfu116 Detected as ceb Wrong 61
With both: Speaker cfu116 Detected as cfu Wrong 10

With cepstrum: Speaker cfx080 Detected as cfx Wrong 8
With acceleration: Speaker cfx080 Detected as chn Wrong 62
With both: Speaker cfx080 Detected as cfx Wrong 10

With cepstrum: Speaker cfx088 Detected as cfx Wrong 8
With acceleration: Speaker cfx088 Detected as chn Wrong 63
With both: Speaker cfx088 Detected as cfx Wrong 10

With cepstrum: Speaker cfx094 Detected as cfx Wrong 8
With acceleration: Speaker cfx094 Detected as cdn Wrong 64
With both: Speaker cfx094 Detected as cfx Wrong 10

With cepstrum: Speaker cga092 Detected as cga Wrong 8
With acceleration: Speaker cga092 Detected as cdn Wrong 65
With both: Speaker cga092 Detected as cga Wrong 10

With cepstrum: Speaker cga098 Detected as cga Wrong 8
With acceleration: Speaker cga098 Detected as chn Wrong 66
With both: Speaker cga098 Detected as cga Wrong 10

With cepstrum: Speaker cga100 Detected as cga Wrong 8
With acceleration: Speaker cga100 Detected as cga Wrong 66
With both: Speaker cga100 Detected as cga Wrong 10

With cepstrum: Speaker cga104 Detected as cga Wrong 8
With acceleration: Speaker cga104 Detected as cga Wrong 66
With both: Speaker cga104 Detected as cga Wrong 10

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With cepstrum: Speaker cge113 Detected as cge Wrong 8
With acceleration: Speaker cge113 Detected as cge Wrong 66
With both: Speaker cge113 Detected as cge Wrong 10

With cepstrum: Speaker cge117 Detected as cge Wrong 8
With acceleration: Speaker cge117 Detected as cge Wrong 66
With both: Speaker cge117 Detected as cge Wrong 10

With cepstrum: Speaker cge120 Detected as cge Wrong 8
With acceleration: Speaker cge120 Detected as cge Wrong 66
With both: Speaker cge120 Detected as cge Wrong 10

With cepstrum: Speaker cge122 Detected as cge Wrong 8
With acceleration: Speaker cge122 Detected as ccz Wrong 67
With both: Speaker cge122 Detected as cge Wrong 10

With cepstrum: Speaker cgm168 Detected as cgm Wrong 8
With acceleration: Speaker cgm168 Detected as cgy Wrong 68
With both: Speaker cgm168 Detected as cgm Wrong 10

With cepstrum: Speaker cgp007 Detected as cgp Wrong 8
With acceleration: Speaker cgp007 Detected as chn Wrong 69
With both: Speaker cgp007 Detected as cgp Wrong 10

With cepstrum: Speaker cgp138 Detected as cgp Wrong 8
With acceleration: Speaker cgp138 Detected as ccv Wrong 70
With both: Speaker cgp138 Detected as cgp Wrong 10

With cepstrum: Speaker cgp143 Detected as cgp Wrong 8
With acceleration: Speaker cgp143 Detected as cfs Wrong 71
With both: Speaker cgp143 Detected as cgp Wrong 10

With cepstrum: Speaker cgp152 Detected as cgp Wrong 8
With acceleration: Speaker cgp152 Detected as chn Wrong 72
With both: Speaker cgp152 Detected as cdn Wrong 11

With cepstrum: Speaker cgp176 Detected as cdk Wrong 9
With acceleration: Speaker cgp176 Detected as chn Wrong 73
With both: Speaker cgp176 Detected as cdn Wrong 12

With cepstrum: Speaker cgx079 Detected as cgx Wrong 9
With acceleration: Speaker cgx079 Detected as cgx Wrong 73
With both: Speaker cgx079 Detected as cgx Wrong 12

With cepstrum: Speaker cgx081 Detected as cgx Wrong 9
With acceleration: Speaker cgx081 Detected as chj Wrong 74
With both: Speaker cgx081 Detected as cgx Wrong 12

With cepstrum: Speaker cgx096 Detected as cgx Wrong 9
With acceleration: Speaker cgx096 Detected as chs Wrong 75
With both: Speaker cgx096 Detected as cgx Wrong 12

With cepstrum: Speaker cgy117 Detected as cgy Wrong 9
With acceleration: Speaker cgy117 Detected as cgy Wrong 75
With both: Speaker cgy117 Detected as cgy Wrong 12

With cepstrum: Speaker chc098 Detected as chc Wrong 9
With acceleration: Speaker chc098 Detected as chn Wrong 76
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With both: Speaker chc098 Detected as chc Wrong 12

With cepstrum: Speaker chg124 Detected as chg Wrong 9
With acceleration: Speaker chg124 Detected as chn Wrong 77
With both: Speaker chg124 Detected as chg Wrong 12

With cepstrum: Speaker chg126 Detected as chg Wrong 9
With acceleration: Speaker chg126 Detected as chg Wrong 77
With both: Speaker chg126 Detected as chg Wrong 12

With cepstrum: Speaker chg173 Detected as chg Wrong 9
With acceleration: Speaker chg173 Detected as chg Wrong 77
With both: Speaker chg173 Detected as chg Wrong 12

With cepstrum: Speaker chg176 Detected as chg Wrong 9
With acceleration: Speaker chg176 Detected as chg Wrong 77
With both: Speaker chg176 Detected as chg Wrong 12

With cepstrum: Speaker chg187 Detected as chg Wrong 9
With acceleration: Speaker chg187 Detected as chg Wrong 77
With both: Speaker chg187 Detected as chg Wrong 12

With cepstrum: Speaker chg197 Detected as chg Wrong 9
With acceleration: Speaker chg197 Detected as chg Wrong 77
With both: Speaker chg197 Detected as chg Wrong 12

With cepstrum: Speaker chg203 Detected as chg Wrong 9
With acceleration: Speaker chg203 Detected as chg Wrong 77
With both: Speaker chg203 Detected as chg Wrong 12

With cepstrum: Speaker chg209 Detected as cdk Wrong 10
With acceleration: Speaker chg209 Detected as chg Wrong 77
With both: Speaker chg209 Detected as chg Wrong 12

With cepstrum: Speaker chj037 Detected as chj Wrong 10
With acceleration: Speaker chj037 Detected as chn Wrong 78
With both: Speaker chj037 Detected as chj Wrong 12

With cepstrum: Speaker chj039 Detected as chj Wrong 10
With acceleration: Speaker chj039 Detected as chn Wrong 79
With both: Speaker chj039 Detected as chj Wrong 12

With cepstrum: Speaker chj043 Detected as chj Wrong 10
With acceleration: Speaker chj043 Detected as chn Wrong 80
With both: Speaker chj043 Detected as chj Wrong 12

With cepstrum: Speaker chj044 Detected as chj Wrong 10
With acceleration: Speaker chj044 Detected as chj Wrong 80
With both: Speaker chj044 Detected as chj Wrong 12

With cepstrum: Speaker chj052 Detected as chj Wrong 10
With acceleration: Speaker chj052 Detected as chj Wrong 80
With both: Speaker chj052 Detected as chj Wrong 12

With cepstrum: Speaker chj206 Detected as chj Wrong 10
With acceleration: Speaker chj206 Detected as chn Wrong 81
With both: Speaker chj206 Detected as chj Wrong 12
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With cepstrum: Speaker chj210 Detected as chj Wrong 10
With acceleration: Speaker chj210 Detected as chn Wrong 82
With both: Speaker chj210 Detected as chj Wrong 12

With cepstrum: Speaker chj212 Detected as chj Wrong 10
With acceleration: Speaker chj212 Detected as chn Wrong 83
With both: Speaker chj212 Detected as chj Wrong 12

With cepstrum: Speaker chj232 Detected as chj Wrong 10
With acceleration: Speaker chj232 Detected as chn Wrong 84
With both: Speaker chj232 Detected as chj Wrong 12

With cepstrum: Speaker chj241 Detected as chj Wrong 10
With acceleration: Speaker chj241 Detected as ckb Wrong 85
With both: Speaker chj241 Detected as chj Wrong 12

With cepstrum: Speaker chn110 Detected as chn Wrong 10
With acceleration: Speaker chn110 Detected as chn Wrong 85
With both: Speaker chn110 Detected as chn Wrong 12

With cepstrum: Speaker chn116 Detected as chn Wrong 10
With acceleration: Speaker chn116 Detected as chn Wrong 85
With both: Speaker chn116 Detected as chn Wrong 12

With cepstrum: Speaker chn118 Detected as chn Wrong 10
With acceleration: Speaker chn118 Detected as chn Wrong 85
With both: Speaker chn118 Detected as chn Wrong 12

With cepstrum: Speaker chs072 Detected as chs Wrong 10
With acceleration: Speaker chs072 Detected as cdi Wrong 86
With both: Speaker chs072 Detected as chs Wrong 12

With cepstrum: Speaker chs095 Detected as chs Wrong 10
With acceleration: Speaker chs095 Detected as chs Wrong 86
With both: Speaker chs095 Detected as chs Wrong 12

With cepstrum: Speaker chs096 Detected as chs Wrong 10
With acceleration: Speaker chs096 Detected as cfs Wrong 87
With both: Speaker chs096 Detected as chs Wrong 12

With cepstrum: Speaker chs109 Detected as chy Wrong 11
With acceleration: Speaker chs109 Detected as cfs Wrong 88
With both: Speaker chs109 Detected as chy Wrong 13

With cepstrum: Speaker chy130 Detected as chy Wrong 11
With acceleration: Speaker chy130 Detected as chn Wrong 89
With both: Speaker chy130 Detected as chy Wrong 13

With cepstrum: Speaker cic140 Detected as cic Wrong 11
With acceleration: Speaker cic140 Detected as cfs Wrong 90
With both: Speaker cic140 Detected as cic Wrong 13

With cepstrum: Speaker cic142 Detected as cic Wrong 11
With acceleration: Speaker cic142 Detected as cic Wrong 90
With both: Speaker cic142 Detected as cic Wrong 13

With cepstrum: Speaker cic146 Detected as cic Wrong 11
With acceleration: Speaker cic146 Detected as chn Wrong 91
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With both: Speaker cic146 Detected as cic Wrong 13

With cepstrum: Speaker cif074 Detected as cif Wrong 11
With acceleration: Speaker cif074 Detected as chn Wrong 92
With both: Speaker cif074 Detected as cif Wrong 13

With cepstrum: Speaker cif076 Detected as cif Wrong 11
With acceleration: Speaker cif076 Detected as cgy Wrong 93
With both: Speaker cif076 Detected as cif Wrong 13

With cepstrum: Speaker cif078 Detected as cif Wrong 11
With acceleration: Speaker cif078 Detected as cif Wrong 93
With both: Speaker cif078 Detected as cif Wrong 13

With cepstrum: Speaker cif088 Detected as cif Wrong 11
With acceleration: Speaker cif088 Detected as chn Wrong 94
With both: Speaker cif088 Detected as cif Wrong 13

With cepstrum: Speaker cif100 Detected as cif Wrong 11
With acceleration: Speaker cif100 Detected as ckb Wrong 95
With both: Speaker cif100 Detected as cif Wrong 13

With cepstrum: Speaker cii102 Detected as cii Wrong 11
With acceleration: Speaker cii102 Detected as chn Wrong 96
With both: Speaker cii102 Detected as cgx Wrong 14

With cepstrum: Speaker cii104 Detected as cii Wrong 11
With acceleration: Speaker cii104 Detected as chn Wrong 97
With both: Speaker cii104 Detected as cii Wrong 14

With cepstrum: Speaker cii109 Detected as cii Wrong 11
With acceleration: Speaker cii109 Detected as chn Wrong 98
With both: Speaker cii109 Detected as cii Wrong 14

With cepstrum: Speaker cik182 Detected as chj Wrong 12
With acceleration: Speaker cik182 Detected as ckb Wrong 99
With both: Speaker cik182 Detected as chj Wrong 15

With cepstrum: Speaker cik193 Detected as cik Wrong 12
With acceleration: Speaker cik193 Detected as cii Wrong 100
With both: Speaker cik193 Detected as cik Wrong 15

With cepstrum: Speaker cik195 Detected as cik Wrong 12
With acceleration: Speaker cik195 Detected as cdt Wrong 101
With both: Speaker cik195 Detected as chc Wrong 16

With cepstrum: Speaker cin013 Detected as cin Wrong 12
With acceleration: Speaker cin013 Detected as cin Wrong 101
With both: Speaker cin013 Detected as cin Wrong 16

With cepstrum: Speaker cin023 Detected as cin Wrong 12
With acceleration: Speaker cin023 Detected as cin Wrong 101
With both: Speaker cin023 Detected as cin Wrong 16

With cepstrum: Speaker cjl055 Detected as cjl Wrong 12
With acceleration: Speaker cjl055 Detected as chn Wrong 102
With both: Speaker cjl055 Detected as cjl Wrong 16
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With cepstrum: Speaker cjl060 Detected as cjl Wrong 12
With acceleration: Speaker cjl060 Detected as cjl Wrong 102
With both: Speaker cjl060 Detected as cjl Wrong 16

With cepstrum: Speaker ckb053 Detected as ckb Wrong 12
With acceleration: Speaker ckb053 Detected as ckb Wrong 102
With both: Speaker ckb053 Detected as ckb Wrong 16

With cepstrum: Speaker ckb062 Detected as ckb Wrong 12
With acceleration: Speaker ckb062 Detected as ckb Wrong 102
With both: Speaker ckb062 Detected as ckb Wrong 16

With cepstrum: Speaker ckb066 Detected as ckb Wrong 12
With acceleration: Speaker ckb066 Detected as cii Wrong 103
With both: Speaker ckb066 Detected as ckb Wrong 16

With cepstrum: Speaker ckb071 Detected as cel Wrong 13
With acceleration: Speaker ckb071 Detected as ckb Wrong 103
With both: Speaker ckb071 Detected as ckb Wrong 16

With cepstrum: Speaker ckb074 Detected as ckb Wrong 13
With acceleration: Speaker ckb074 Detected as ckb Wrong 103
With both: Speaker ckb074 Detected as ckb Wrong 16

With cepstrum: Speaker ckb078 Detected as ckb Wrong 13
With acceleration: Speaker ckb078 Detected as ckb Wrong 103
With both: Speaker ckb078 Detected as ckb Wrong 16

With cepstrum: Speaker ckc058 Detected as ckc Wrong 13
With acceleration: Speaker ckc058 Detected as chn Wrong 104
With both: Speaker ckc058 Detected as ckc Wrong 16

With cepstrum: Speaker ckc067 Detected as ckc Wrong 13
With acceleration: Speaker ckc067 Detected as ckc Wrong 104
With both: Speaker ckc067 Detected as ckc Wrong 16

With cepstrum: Speaker ckc069 Detected as ckc Wrong 13
With acceleration: Speaker ckc069 Detected as ckb Wrong 105
With both: Speaker ckc069 Detected as ckc Wrong 16

With cepstrum: Speaker ckc077 Detected as ckc Wrong 13
With acceleration: Speaker ckc077 Detected as chn Wrong 106
With both: Speaker ckc077 Detected as ckc Wrong 16

With cepstrum: Speaker ckd088 Detected as ckd Wrong 13
With acceleration: Speaker ckd088 Detected as ckd Wrong 106
With both: Speaker ckd088 Detected as ckd Wrong 16

With cepstrum: Speaker ckd124 Detected as ckd Wrong 13
With acceleration: Speaker ckd124 Detected as chn Wrong 107
With both: Speaker ckd124 Detected as ckd Wrong 16

With cepstrum: Speaker ckd133 Detected as ckd Wrong 13
With acceleration: Speaker ckd133 Detected as chn Wrong 108
With both: Speaker ckd133 Detected as ckd Wrong 16

percent correct cepstrum = 91.823899
percent correct acceleration cepstrum = 32.075472
```



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percent correct both = 89.937107
```

With Liftered Cepstrum and Delta Cepstrum

With liftered cepstrum: Speaker ccd064 Detected as ccd Wrong 0
With delta: Speaker ccd064 Detected as ccd Wrong 0
With both: Speaker ccd064 Detected as ccd Wrong 0

With liftered cepstrum: Speaker ccd078 Detected as cii Wrong 1
With delta: Speaker ccd078 Detected as ccz Wrong 1
With both: Speaker ccd078 Detected as ccz Wrong 1

With liftered cepstrum: Speaker ccd094 Detected as ccd Wrong 1
With delta: Speaker ccd094 Detected as ccd Wrong 1
With both: Speaker ccd094 Detected as ccd Wrong 1

With liftered cepstrum: Speaker cch140 Detected as cch Wrong 1
With delta: Speaker cch140 Detected as cch Wrong 1
With both: Speaker cch140 Detected as cch Wrong 1

With liftered cepstrum: Speaker cch142 Detected as cch Wrong 1
With delta: Speaker cch142 Detected as cch Wrong 1
With both: Speaker cch142 Detected as cch Wrong 1

With liftered cepstrum: Speaker cch149 Detected as cch Wrong 1
With delta: Speaker cch149 Detected as cch Wrong 1
With both: Speaker cch149 Detected as cch Wrong 1

With liftered cepstrum: Speaker ccv035 Detected as ccv Wrong 1
With delta: Speaker ccv035 Detected as cdn Wrong 2
With both: Speaker ccv035 Detected as ccv Wrong 1

With liftered cepstrum: Speaker ccv039 Detected as ccv Wrong 1
With delta: Speaker ccv039 Detected as ccv Wrong 2
With both: Speaker ccv039 Detected as ccv Wrong 1

With liftered cepstrum: Speaker ccv050 Detected as cgx Wrong 2
With delta: Speaker ccv050 Detected as cfs Wrong 3
With both: Speaker ccv050 Detected as ccv Wrong 1

With liftered cepstrum: Speaker ccv052 Detected as ccv Wrong 2
With delta: Speaker ccv052 Detected as chn Wrong 4
With both: Speaker ccv052 Detected as ccv Wrong 1

With liftered cepstrum: Speaker ccz041 Detected as ccz Wrong 2
With delta: Speaker ccz041 Detected as ccz Wrong 4
With both: Speaker ccz041 Detected as ccz Wrong 1

With liftered cepstrum: Speaker ccz043 Detected as ccz Wrong 2
With delta: Speaker ccz043 Detected as ccz Wrong 4
With both: Speaker ccz043 Detected as ccz Wrong 1

With liftered cepstrum: Speaker cdi009 Detected as cdi Wrong 2
With delta: Speaker cdi009 Detected as cdi Wrong 4
With both: Speaker cdi009 Detected as cdi Wrong 1

With liftered cepstrum: Speaker cdi012 Detected as cdi Wrong 2
With delta: Speaker cdi012 Detected as cdi Wrong 4
With both: Speaker cdi012 Detected as cdi Wrong 1

With liftered cepstrum: Speaker cdi022 Detected as ccz Wrong 3
With delta: Speaker cdi022 Detected as cdi Wrong 4

With both: Speaker cdi022 Detected as ccz Wrong 2

With liftered cepstrum: Speaker cdk061 Detected as cdk Wrong 3
With delta: Speaker cdk061 Detected as cdk Wrong 4
With both: Speaker cdk061 Detected as cdk Wrong 2

With liftered cepstrum: Speaker cdk063 Detected as cdk Wrong 3
With delta: Speaker cdk063 Detected as chn Wrong 5
With both: Speaker cdk063 Detected as cdk Wrong 2

With liftered cepstrum: Speaker cdk065 Detected as cdn Wrong 4
With delta: Speaker cdk065 Detected as cdk Wrong 5
With both: Speaker cdk065 Detected as cdk Wrong 2

With liftered cepstrum: Speaker cdn105 Detected as cdn Wrong 4
With delta: Speaker cdn105 Detected as cdn Wrong 5
With both: Speaker cdn105 Detected as cdn Wrong 2

With liftered cepstrum: Speaker cdn107 Detected as cdn Wrong 4
With delta: Speaker cdn107 Detected as cdn Wrong 5
With both: Speaker cdn107 Detected as cdn Wrong 2

With liftered cepstrum: Speaker cdn122 Detected as cdn Wrong 4
With delta: Speaker cdn122 Detected as cdn Wrong 5
With both: Speaker cdn122 Detected as cdn Wrong 2

With liftered cepstrum: Speaker cdn126 Detected as cdn Wrong 4
With delta: Speaker cdn126 Detected as cdn Wrong 5
With both: Speaker cdn126 Detected as cdn Wrong 2

With liftered cepstrum: Speaker cdn135 Detected as cdn Wrong 4
With delta: Speaker cdn135 Detected as cdn Wrong 5
With both: Speaker cdn135 Detected as cdn Wrong 2

With liftered cepstrum: Speaker cdn139 Detected as cdn Wrong 4
With delta: Speaker cdn139 Detected as cdn Wrong 5
With both: Speaker cdn139 Detected as cdn Wrong 2

With liftered cepstrum: Speaker cdt183 Detected as cdt Wrong 4
With delta: Speaker cdt183 Detected as cdt Wrong 5
With both: Speaker cdt183 Detected as cdt Wrong 2

With liftered cepstrum: Speaker cdt187 Detected as cdt Wrong 4
With delta: Speaker cdt187 Detected as chn Wrong 6
With both: Speaker cdt187 Detected as cdt Wrong 2

With liftered cepstrum: Speaker cdt198 Detected as cdt Wrong 4
With delta: Speaker cdt198 Detected as cel Wrong 7
With both: Speaker cdt198 Detected as cdt Wrong 2

With liftered cepstrum: Speaker cdt237 Detected as cdt Wrong 4
With delta: Speaker cdt237 Detected as chn Wrong 8
With both: Speaker cdt237 Detected as cdt Wrong 2

With liftered cepstrum: Speaker cdv078 Detected as cdv Wrong 4
With delta: Speaker cdv078 Detected as cgx Wrong 9
With both: Speaker cdv078 Detected as cdv Wrong 2

With liftered cepstrum: Speaker cdv080 Detected as cdv Wrong 4
With delta: Speaker cdv080 Detected as ceb Wrong 10
With both: Speaker cdv080 Detected as cdv Wrong 2

With liftered cepstrum: Speaker cdv081 Detected as cdv Wrong 4
With delta: Speaker cdv081 Detected as cii Wrong 11
With both: Speaker cdv081 Detected as cdv Wrong 2

With liftered cepstrum: Speaker cdv095 Detected as cdv Wrong 4
With delta: Speaker cdv095 Detected as cgy Wrong 12
With both: Speaker cdv095 Detected as cdv Wrong 2

With liftered cepstrum: Speaker cdw131 Detected as cdw Wrong 4
With delta: Speaker cdw131 Detected as cdv Wrong 13
With both: Speaker cdw131 Detected as cdw Wrong 2

With liftered cepstrum: Speaker cdw142 Detected as cdw Wrong 4
With delta: Speaker cdw142 Detected as cdw Wrong 13
With both: Speaker cdw142 Detected as cdw Wrong 2

With liftered cepstrum: Speaker cdw145 Detected as cdw Wrong 4
With delta: Speaker cdw145 Detected as cdw Wrong 13
With both: Speaker cdw145 Detected as cdw Wrong 2

With liftered cepstrum: Speaker ceb014 Detected as ceb Wrong 4
With delta: Speaker ceb014 Detected as chn Wrong 14
With both: Speaker ceb014 Detected as ceb Wrong 2

With liftered cepstrum: Speaker ceb015 Detected as ceb Wrong 4
With delta: Speaker ceb015 Detected as ceb Wrong 14
With both: Speaker ceb015 Detected as ceb Wrong 2

With liftered cepstrum: Speaker ceb022 Detected as cin Wrong 5
With delta: Speaker ceb022 Detected as cgx Wrong 15
With both: Speaker ceb022 Detected as ceb Wrong 2

With liftered cepstrum: Speaker cel188 Detected as cel Wrong 5
With delta: Speaker cel188 Detected as cel Wrong 15
With both: Speaker cel188 Detected as cel Wrong 2

With liftered cepstrum: Speaker cel190 Detected as cel Wrong 5
With delta: Speaker cel190 Detected as chn Wrong 16
With both: Speaker cel190 Detected as cel Wrong 2

With liftered cepstrum: Speaker cel192 Detected as cel Wrong 5
With delta: Speaker cel192 Detected as cel Wrong 16
With both: Speaker cel192 Detected as cel Wrong 2

With liftered cepstrum: Speaker cel202 Detected as cel Wrong 5
With delta: Speaker cel202 Detected as cin Wrong 17
With both: Speaker cel202 Detected as cel Wrong 2

With liftered cepstrum: Speaker cel220 Detected as cel Wrong 5
With delta: Speaker cel220 Detected as cgy Wrong 18
With both: Speaker cel220 Detected as cel Wrong 2

With liftered cepstrum: Speaker cem128 Detected as chj Wrong 6
With delta: Speaker cem128 Detected as chn Wrong 19

With both: Speaker cem128 Detected as chj Wrong 3

With liftered cepstrum: Speaker cem131 Detected as cel Wrong 7
With delta: Speaker cem131 Detected as cfs Wrong 20
With both: Speaker cem131 Detected as cel Wrong 4

With liftered cepstrum: Speaker cem137 Detected as chy Wrong 8
With delta: Speaker cem137 Detected as chn Wrong 21
With both: Speaker cem137 Detected as chj Wrong 5

With liftered cepstrum: Speaker cev090 Detected as cev Wrong 8
With delta: Speaker cev090 Detected as cev Wrong 21
With both: Speaker cev090 Detected as cev Wrong 5

With liftered cepstrum: Speaker cev092 Detected as cev Wrong 8
With delta: Speaker cev092 Detected as cev Wrong 21
With both: Speaker cev092 Detected as cev Wrong 5

With liftered cepstrum: Speaker cev094 Detected as cev Wrong 8
With delta: Speaker cev094 Detected as cev Wrong 21
With both: Speaker cev094 Detected as cev Wrong 5

With liftered cepstrum: Speaker cev101 Detected as cev Wrong 8
With delta: Speaker cev101 Detected as cev Wrong 21
With both: Speaker cev101 Detected as cev Wrong 5

With liftered cepstrum: Speaker cev112 Detected as cev Wrong 8
With delta: Speaker cev112 Detected as cev Wrong 21
With both: Speaker cev112 Detected as cev Wrong 5

With liftered cepstrum: Speaker cfi013 Detected as cfi Wrong 8
With delta: Speaker cfi013 Detected as cfi Wrong 21
With both: Speaker cfi013 Detected as cfi Wrong 5

With liftered cepstrum: Speaker cfi018 Detected as cfi Wrong 8
With delta: Speaker cfi018 Detected as cfi Wrong 21
With both: Speaker cfi018 Detected as cfi Wrong 5

With liftered cepstrum: Speaker cfi020 Detected as cfi Wrong 8
With delta: Speaker cfi020 Detected as cfi Wrong 21
With both: Speaker cfi020 Detected as cfi Wrong 5

With liftered cepstrum: Speaker cfi021 Detected as cfi Wrong 8
With delta: Speaker cfi021 Detected as cfi Wrong 21
With both: Speaker cfi021 Detected as cfi Wrong 5

With liftered cepstrum: Speaker cfi024 Detected as cfi Wrong 8
With delta: Speaker cfi024 Detected as cfi Wrong 21
With both: Speaker cfi024 Detected as cfi Wrong 5

With liftered cepstrum: Speaker cfj054 Detected as cfj Wrong 8
With delta: Speaker cfj054 Detected as cdi Wrong 22
With both: Speaker cfj054 Detected as cfj Wrong 5

With liftered cepstrum: Speaker cfj055 Detected as cfj Wrong 8
With delta: Speaker cfj055 Detected as cfj Wrong 22
With both: Speaker cfj055 Detected as cfj Wrong 5

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With liftered cepstrum: Speaker cfj056 Detected as cfj Wrong 8
With delta: Speaker cfj056 Detected as cdn Wrong 23
With both: Speaker cfj056 Detected as cfj Wrong 5

With liftered cepstrum: Speaker cfj057 Detected as cfj Wrong 8
With delta: Speaker cfj057 Detected as cfj Wrong 23
With both: Speaker cfj057 Detected as cfj Wrong 5

With liftered cepstrum: Speaker cfp027 Detected as cfp Wrong 8
With delta: Speaker cfp027 Detected as cfp Wrong 23
With both: Speaker cfp027 Detected as cfp Wrong 5

With liftered cepstrum: Speaker cfp043 Detected as cfp Wrong 8
With delta: Speaker cfp043 Detected as cfp Wrong 23
With both: Speaker cfp043 Detected as cfp Wrong 5

With liftered cepstrum: Speaker cfp048 Detected as cfp Wrong 8
With delta: Speaker cfp048 Detected as cfp Wrong 23
With both: Speaker cfp048 Detected as cfp Wrong 5

With liftered cepstrum: Speaker cfp058 Detected as cfp Wrong 8
With delta: Speaker cfp058 Detected as cfp Wrong 23
With both: Speaker cfp058 Detected as cfp Wrong 5

With liftered cepstrum: Speaker cfp061 Detected as cfp Wrong 8
With delta: Speaker cfp061 Detected as cfp Wrong 23
With both: Speaker cfp061 Detected as cfp Wrong 5

With liftered cepstrum: Speaker cfs038 Detected as cfs Wrong 8
With delta: Speaker cfs038 Detected as cfs Wrong 23
With both: Speaker cfs038 Detected as cfs Wrong 5

With liftered cepstrum: Speaker cfs041 Detected as cfs Wrong 8
With delta: Speaker cfs041 Detected as cfs Wrong 23
With both: Speaker cfs041 Detected as cfs Wrong 5

With liftered cepstrum: Speaker cfs045 Detected as cfs Wrong 8
With delta: Speaker cfs045 Detected as cfs Wrong 23
With both: Speaker cfs045 Detected as cfs Wrong 5

With liftered cepstrum: Speaker cfu025 Detected as cfu Wrong 8
With delta: Speaker cfu025 Detected as cgx Wrong 24
With both: Speaker cfu025 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu034 Detected as cfu Wrong 8
With delta: Speaker cfu034 Detected as cfu Wrong 24
With both: Speaker cfu034 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu043 Detected as cfu Wrong 8
With delta: Speaker cfu043 Detected as cfu Wrong 24
With both: Speaker cfu043 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu071 Detected as cfu Wrong 8
With delta: Speaker cfu071 Detected as cii Wrong 25
With both: Speaker cfu071 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu075 Detected as cfu Wrong 8
With delta: Speaker cfu075 Detected as ceb Wrong 26
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With both: Speaker cfu075 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu079 Detected as cfu Wrong 8
With delta: Speaker cfu079 Detected as cgy Wrong 27
With both: Speaker cfu079 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu089 Detected as cfu Wrong 8
With delta: Speaker cfu089 Detected as cfu Wrong 27
With both: Speaker cfu089 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu095 Detected as cfu Wrong 8
With delta: Speaker cfu095 Detected as cfu Wrong 27
With both: Speaker cfu095 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu099 Detected as cfu Wrong 8
With delta: Speaker cfu099 Detected as cgy Wrong 28
With both: Speaker cfu099 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu109 Detected as cfu Wrong 8
With delta: Speaker cfu109 Detected as cfu Wrong 28
With both: Speaker cfu109 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu112 Detected as cfu Wrong 8
With delta: Speaker cfu112 Detected as cfu Wrong 28
With both: Speaker cfu112 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfu116 Detected as cfu Wrong 8
With delta: Speaker cfu116 Detected as cgy Wrong 29
With both: Speaker cfu116 Detected as cfu Wrong 5

With liftered cepstrum: Speaker cfx080 Detected as cfx Wrong 8
With delta: Speaker cfx080 Detected as cfx Wrong 29
With both: Speaker cfx080 Detected as cfx Wrong 5

With liftered cepstrum: Speaker cfx088 Detected as cfx Wrong 8
With delta: Speaker cfx088 Detected as cdn Wrong 30
With both: Speaker cfx088 Detected as cfx Wrong 5

With liftered cepstrum: Speaker cfx094 Detected as cfx Wrong 8
With delta: Speaker cfx094 Detected as cdn Wrong 31
With both: Speaker cfx094 Detected as cfx Wrong 5

With liftered cepstrum: Speaker cga092 Detected as cga Wrong 8
With delta: Speaker cga092 Detected as cga Wrong 31
With both: Speaker cga092 Detected as cga Wrong 5

With liftered cepstrum: Speaker cga098 Detected as cga Wrong 8
With delta: Speaker cga098 Detected as cga Wrong 31
With both: Speaker cga098 Detected as cga Wrong 5

With liftered cepstrum: Speaker cga100 Detected as cga Wrong 8
With delta: Speaker cga100 Detected as cga Wrong 31
With both: Speaker cga100 Detected as cga Wrong 5

With liftered cepstrum: Speaker cga104 Detected as cga Wrong 8
With delta: Speaker cga104 Detected as cga Wrong 31
With both: Speaker cga104 Detected as cga Wrong 5
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With liftered cepstrum: Speaker cge113 Detected as cge Wrong 8
With delta: Speaker cge113 Detected as cge Wrong 31
With both: Speaker cge113 Detected as cge Wrong 5

With liftered cepstrum: Speaker cge117 Detected as cge Wrong 8
With delta: Speaker cge117 Detected as cge Wrong 31
With both: Speaker cge117 Detected as cge Wrong 5

With liftered cepstrum: Speaker cge120 Detected as cge Wrong 8
With delta: Speaker cge120 Detected as cge Wrong 31
With both: Speaker cge120 Detected as cge Wrong 5

With liftered cepstrum: Speaker cge122 Detected as cge Wrong 8
With delta: Speaker cge122 Detected as cge Wrong 31
With both: Speaker cge122 Detected as cge Wrong 5

With liftered cepstrum: Speaker cgm168 Detected as cgm Wrong 8
With delta: Speaker cgm168 Detected as cgm Wrong 31
With both: Speaker cgm168 Detected as cgm Wrong 5

With liftered cepstrum: Speaker cgp007 Detected as cgp Wrong 8
With delta: Speaker cgp007 Detected as chn Wrong 32
With both: Speaker cgp007 Detected as cgp Wrong 5

With liftered cepstrum: Speaker cgp138 Detected as cgp Wrong 8
With delta: Speaker cgp138 Detected as cfx Wrong 33
With both: Speaker cgp138 Detected as cgp Wrong 5

With liftered cepstrum: Speaker cgp143 Detected as cch Wrong 9
With delta: Speaker cgp143 Detected as cdi Wrong 34
With both: Speaker cgp143 Detected as cgp Wrong 5

With liftered cepstrum: Speaker cgp152 Detected as cdn Wrong 10
With delta: Speaker cgp152 Detected as cgy Wrong 35
With both: Speaker cgp152 Detected as cgp Wrong 5

With liftered cepstrum: Speaker cgp176 Detected as cch Wrong 11
With delta: Speaker cgp176 Detected as cfs Wrong 36
With both: Speaker cgp176 Detected as cgp Wrong 5

With liftered cepstrum: Speaker cgx079 Detected as cgx Wrong 11
With delta: Speaker cgx079 Detected as cgx Wrong 36
With both: Speaker cgx079 Detected as cgx Wrong 5

With liftered cepstrum: Speaker cgx081 Detected as cgx Wrong 11
With delta: Speaker cgx081 Detected as cgx Wrong 36
With both: Speaker cgx081 Detected as cgx Wrong 5

With liftered cepstrum: Speaker cgx096 Detected as cgx Wrong 11
With delta: Speaker cgx096 Detected as cel Wrong 37
With both: Speaker cgx096 Detected as cgx Wrong 5

With liftered cepstrum: Speaker cgy117 Detected as cgy Wrong 11
With delta: Speaker cgy117 Detected as cgy Wrong 37
With both: Speaker cgy117 Detected as cgy Wrong 5

With liftered cepstrum: Speaker chc098 Detected as cgx Wrong 12
With delta: Speaker chc098 Detected as chc Wrong 37
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With both: Speaker chc098 Detected as cii Wrong 6

With liftered cepstrum: Speaker chg124 Detected as chg Wrong 12
With delta: Speaker chg124 Detected as ccz Wrong 38
With both: Speaker chg124 Detected as chg Wrong 6

With liftered cepstrum: Speaker chg126 Detected as chg Wrong 12
With delta: Speaker chg126 Detected as chg Wrong 38
With both: Speaker chg126 Detected as chg Wrong 6

With liftered cepstrum: Speaker chg173 Detected as chg Wrong 12
With delta: Speaker chg173 Detected as chg Wrong 38
With both: Speaker chg173 Detected as chg Wrong 6

With liftered cepstrum: Speaker chg176 Detected as chg Wrong 12
With delta: Speaker chg176 Detected as chg Wrong 38
With both: Speaker chg176 Detected as chg Wrong 6

With liftered cepstrum: Speaker chg187 Detected as chg Wrong 12
With delta: Speaker chg187 Detected as chg Wrong 38
With both: Speaker chg187 Detected as chg Wrong 6

With liftered cepstrum: Speaker chg197 Detected as chg Wrong 12
With delta: Speaker chg197 Detected as chg Wrong 38
With both: Speaker chg197 Detected as chg Wrong 6

With liftered cepstrum: Speaker chg203 Detected as chg Wrong 12
With delta: Speaker chg203 Detected as chg Wrong 38
With both: Speaker chg203 Detected as chg Wrong 6

With liftered cepstrum: Speaker chg209 Detected as chg Wrong 12
With delta: Speaker chg209 Detected as chg Wrong 38
With both: Speaker chg209 Detected as chg Wrong 6

With liftered cepstrum: Speaker chj037 Detected as chj Wrong 12
With delta: Speaker chj037 Detected as chj Wrong 38
With both: Speaker chj037 Detected as chj Wrong 6

With liftered cepstrum: Speaker chj039 Detected as chj Wrong 12
With delta: Speaker chj039 Detected as chn Wrong 39
With both: Speaker chj039 Detected as chj Wrong 6

With liftered cepstrum: Speaker chj043 Detected as chj Wrong 12
With delta: Speaker chj043 Detected as chj Wrong 39
With both: Speaker chj043 Detected as chj Wrong 6

With liftered cepstrum: Speaker chj044 Detected as chj Wrong 12
With delta: Speaker chj044 Detected as chj Wrong 39
With both: Speaker chj044 Detected as chj Wrong 6

With liftered cepstrum: Speaker chj052 Detected as chj Wrong 12
With delta: Speaker chj052 Detected as chj Wrong 39
With both: Speaker chj052 Detected as chj Wrong 6

With liftered cepstrum: Speaker chj206 Detected as chj Wrong 12
With delta: Speaker chj206 Detected as cgy Wrong 40
With both: Speaker chj206 Detected as chj Wrong 6
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With liftered cepstrum: Speaker chj210 Detected as chj Wrong 12
With delta: Speaker chj210 Detected as chj Wrong 40
With both: Speaker chj210 Detected as chj Wrong 6

With liftered cepstrum: Speaker chj212 Detected as chj Wrong 12
With delta: Speaker chj212 Detected as chj Wrong 40
With both: Speaker chj212 Detected as chj Wrong 6

With liftered cepstrum: Speaker chj232 Detected as chj Wrong 12
With delta: Speaker chj232 Detected as chj Wrong 40
With both: Speaker chj232 Detected as chj Wrong 6

With liftered cepstrum: Speaker chj241 Detected as chj Wrong 12
With delta: Speaker chj241 Detected as chj Wrong 40
With both: Speaker chj241 Detected as chj Wrong 6

With liftered cepstrum: Speaker chn110 Detected as chn Wrong 12
With delta: Speaker chn110 Detected as chn Wrong 40
With both: Speaker chn110 Detected as chn Wrong 6

With liftered cepstrum: Speaker chn116 Detected as chn Wrong 12
With delta: Speaker chn116 Detected as chn Wrong 40
With both: Speaker chn116 Detected as chn Wrong 6

With liftered cepstrum: Speaker chn118 Detected as chn Wrong 12
With delta: Speaker chn118 Detected as cii Wrong 41
With both: Speaker chn118 Detected as chn Wrong 6

With liftered cepstrum: Speaker chs072 Detected as chs Wrong 12
With delta: Speaker chs072 Detected as chg Wrong 42
With both: Speaker chs072 Detected as chs Wrong 6

With liftered cepstrum: Speaker chs095 Detected as chs Wrong 12
With delta: Speaker chs095 Detected as chs Wrong 42
With both: Speaker chs095 Detected as chs Wrong 6

With liftered cepstrum: Speaker chs096 Detected as chs Wrong 12
With delta: Speaker chs096 Detected as chy Wrong 43
With both: Speaker chs096 Detected as chs Wrong 6

With liftered cepstrum: Speaker chs109 Detected as cic Wrong 13
With delta: Speaker chs109 Detected as chs Wrong 43
With both: Speaker chs109 Detected as cic Wrong 7

With liftered cepstrum: Speaker chy130 Detected as chy Wrong 13
With delta: Speaker chy130 Detected as chn Wrong 44
With both: Speaker chy130 Detected as chy Wrong 7

With liftered cepstrum: Speaker cic140 Detected as cic Wrong 13
With delta: Speaker cic140 Detected as cic Wrong 44
With both: Speaker cic140 Detected as cic Wrong 7

With liftered cepstrum: Speaker cic142 Detected as cic Wrong 13
With delta: Speaker cic142 Detected as cic Wrong 44
With both: Speaker cic142 Detected as cic Wrong 7

With liftered cepstrum: Speaker cic146 Detected as cic Wrong 13
With delta: Speaker cic146 Detected as chn Wrong 45
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With both: Speaker cic146 Detected as cic Wrong 7

With liftered cepstrum: Speaker cif074 Detected as cif Wrong 13
With delta: Speaker cif074 Detected as cif Wrong 45
With both: Speaker cif074 Detected as cif Wrong 7

With liftered cepstrum: Speaker cif076 Detected as cif Wrong 13
With delta: Speaker cif076 Detected as chn Wrong 46
With both: Speaker cif076 Detected as cif Wrong 7

With liftered cepstrum: Speaker cif078 Detected as cif Wrong 13
With delta: Speaker cif078 Detected as cif Wrong 46
With both: Speaker cif078 Detected as cif Wrong 7

With liftered cepstrum: Speaker cif088 Detected as cif Wrong 13
With delta: Speaker cif088 Detected as cif Wrong 46
With both: Speaker cif088 Detected as cif Wrong 7

With liftered cepstrum: Speaker cif100 Detected as cif Wrong 13
With delta: Speaker cif100 Detected as cif Wrong 46
With both: Speaker cif100 Detected as cif Wrong 7

With liftered cepstrum: Speaker cii102 Detected as cii Wrong 13
With delta: Speaker cii102 Detected as cgx Wrong 47
With both: Speaker cii102 Detected as cii Wrong 7

With liftered cepstrum: Speaker cii104 Detected as cii Wrong 13
With delta: Speaker cii104 Detected as cii Wrong 47
With both: Speaker cii104 Detected as cii Wrong 7

With liftered cepstrum: Speaker cii109 Detected as cii Wrong 13
With delta: Speaker cii109 Detected as chn Wrong 48
With both: Speaker cii109 Detected as cii Wrong 7

With liftered cepstrum: Speaker cik182 Detected as cik Wrong 13
With delta: Speaker cik182 Detected as cgy Wrong 49
With both: Speaker cik182 Detected as cik Wrong 7

With liftered cepstrum: Speaker cik193 Detected as cik Wrong 13
With delta: Speaker cik193 Detected as cik Wrong 49
With both: Speaker cik193 Detected as cik Wrong 7

With liftered cepstrum: Speaker cik195 Detected as cik Wrong 13
With delta: Speaker cik195 Detected as chc Wrong 50
With both: Speaker cik195 Detected as cik Wrong 7

With liftered cepstrum: Speaker cin013 Detected as cin Wrong 13
With delta: Speaker cin013 Detected as cfp Wrong 51
With both: Speaker cin013 Detected as cin Wrong 7

With liftered cepstrum: Speaker cin023 Detected as cin Wrong 13
With delta: Speaker cin023 Detected as cin Wrong 51
With both: Speaker cin023 Detected as cin Wrong 7

With liftered cepstrum: Speaker cjl055 Detected as cjl Wrong 13
With delta: Speaker cjl055 Detected as cjl Wrong 51
With both: Speaker cjl055 Detected as cjl Wrong 7
```

```
With liftered cepstrum: Speaker cjl060 Detected as cjl Wrong 13
With delta: Speaker cjl060 Detected as cjl Wrong 51
With both: Speaker cjl060 Detected as cjl Wrong 7

With liftered cepstrum: Speaker ckb053 Detected as ckb Wrong 13
With delta: Speaker ckb053 Detected as ckb Wrong 51
With both: Speaker ckb053 Detected as ckb Wrong 7

With liftered cepstrum: Speaker ckb062 Detected as ckb Wrong 13
With delta: Speaker ckb062 Detected as ckb Wrong 51
With both: Speaker ckb062 Detected as ckb Wrong 7

With liftered cepstrum: Speaker ckb066 Detected as ckb Wrong 13
With delta: Speaker ckb066 Detected as ckb Wrong 51
With both: Speaker ckb066 Detected as ckb Wrong 7

With liftered cepstrum: Speaker ckb071 Detected as cel Wrong 14
With delta: Speaker ckb071 Detected as cdi Wrong 52
With both: Speaker ckb071 Detected as ckb Wrong 7

With liftered cepstrum: Speaker ckb074 Detected as ckb Wrong 14
With delta: Speaker ckb074 Detected as ckb Wrong 52
With both: Speaker ckb074 Detected as ckb Wrong 7

With liftered cepstrum: Speaker ckb078 Detected as ckb Wrong 14
With delta: Speaker ckb078 Detected as ckb Wrong 52
With both: Speaker ckb078 Detected as ckb Wrong 7

With liftered cepstrum: Speaker ckc058 Detected as ckc Wrong 14
With delta: Speaker ckc058 Detected as ckc Wrong 52
With both: Speaker ckc058 Detected as ckc Wrong 7

With liftered cepstrum: Speaker ckc067 Detected as ckc Wrong 14
With delta: Speaker ckc067 Detected as ckc Wrong 52
With both: Speaker ckc067 Detected as ckc Wrong 7

With liftered cepstrum: Speaker ckc069 Detected as ckc Wrong 14
With delta: Speaker ckc069 Detected as ckc Wrong 52
With both: Speaker ckc069 Detected as ckc Wrong 7

With liftered cepstrum: Speaker ckc077 Detected as ckc Wrong 14
With delta: Speaker ckc077 Detected as ckc Wrong 52
With both: Speaker ckc077 Detected as ckc Wrong 7

With liftered cepstrum: Speaker ckd088 Detected as ckd Wrong 14
With delta: Speaker ckd088 Detected as ckd Wrong 52
With both: Speaker ckd088 Detected as ckd Wrong 7

With liftered cepstrum: Speaker ckd124 Detected as ckd Wrong 14
With delta: Speaker ckd124 Detected as cin Wrong 53
With both: Speaker ckd124 Detected as ckd Wrong 7

With liftered cepstrum: Speaker ckd133 Detected as ckd Wrong 14
With delta: Speaker ckd133 Detected as ckd Wrong 53
With both: Speaker ckd133 Detected as ckd Wrong 7

percent correct liftered cepstrum = 91.194969
percent correct delta cepstrum = 66.666667
```



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percent correct both = 95.597484
```

With Liftered Cesptrum and Acceleration Cepstrum

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With liftered cepstrum: Speaker ccd064 Detected as ccd Wrong 0
With acceleration: Speaker ccd064 Detected as cgy Wrong 1
With both: Speaker ccd064 Detected as ccd Wrong 0

With liftered cepstrum: Speaker ccd078 Detected as cii Wrong 1
With acceleration: Speaker ccd078 Detected as ccz Wrong 2
With both: Speaker ccd078 Detected as ccz Wrong 1

With liftered cepstrum: Speaker ccd094 Detected as ccd Wrong 1
With acceleration: Speaker ccd094 Detected as chn Wrong 3
With both: Speaker ccd094 Detected as ccd Wrong 1

With liftered cepstrum: Speaker cch140 Detected as cch Wrong 1
With acceleration: Speaker cch140 Detected as chn Wrong 4
With both: Speaker cch140 Detected as cch Wrong 1

With liftered cepstrum: Speaker cch142 Detected as cch Wrong 1
With acceleration: Speaker cch142 Detected as cfs Wrong 5
With both: Speaker cch142 Detected as cch Wrong 1

With liftered cepstrum: Speaker cch149 Detected as cch Wrong 1
With acceleration: Speaker cch149 Detected as chn Wrong 6
With both: Speaker cch149 Detected as cch Wrong 1

With liftered cepstrum: Speaker ccv035 Detected as ccv Wrong 1
With acceleration: Speaker ccv035 Detected as cfs Wrong 7
With both: Speaker ccv035 Detected as ccv Wrong 1

With liftered cepstrum: Speaker ccv039 Detected as ccv Wrong 1
With acceleration: Speaker ccv039 Detected as ccv Wrong 7
With both: Speaker ccv039 Detected as ccv Wrong 1

With liftered cepstrum: Speaker ccv050 Detected as cgx Wrong 2
With acceleration: Speaker ccv050 Detected as cfs Wrong 8
With both: Speaker ccv050 Detected as cii Wrong 2

With liftered cepstrum: Speaker ccv052 Detected as ccv Wrong 2
With acceleration: Speaker ccv052 Detected as cfs Wrong 9
With both: Speaker ccv052 Detected as ccv Wrong 2

With liftered cepstrum: Speaker ccz041 Detected as ccz Wrong 2
With acceleration: Speaker ccz041 Detected as chn Wrong 10
With both: Speaker ccz041 Detected as ccz Wrong 2

With liftered cepstrum: Speaker ccz043 Detected as ccz Wrong 2
With acceleration: Speaker ccz043 Detected as chc Wrong 11
With both: Speaker ccz043 Detected as ccz Wrong 2

With liftered cepstrum: Speaker cdi009 Detected as cdi Wrong 2
With acceleration: Speaker cdi009 Detected as cdi Wrong 11
With both: Speaker cdi009 Detected as cdi Wrong 2

With liftered cepstrum: Speaker cdi012 Detected as cdi Wrong 2
With acceleration: Speaker cdi012 Detected as chn Wrong 12
With both: Speaker cdi012 Detected as cdi Wrong 2

With liftered cepstrum: Speaker cdi022 Detected as ccz Wrong 3
With acceleration: Speaker cdi022 Detected as chn Wrong 13
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With both: Speaker cdi022 Detected as chn Wrong 3

With liftered cepstrum: Speaker cdk061 Detected as cdk Wrong 3
With acceleration: Speaker cdk061 Detected as cdk Wrong 13
With both: Speaker cdk061 Detected as cdk Wrong 3

With liftered cepstrum: Speaker cdk063 Detected as cdk Wrong 3
With acceleration: Speaker cdk063 Detected as chn Wrong 14
With both: Speaker cdk063 Detected as cdk Wrong 3

With liftered cepstrum: Speaker cdk065 Detected as cdn Wrong 4
With acceleration: Speaker cdk065 Detected as ceb Wrong 15
With both: Speaker cdk065 Detected as cdn Wrong 4

With liftered cepstrum: Speaker cdn105 Detected as cdn Wrong 4
With acceleration: Speaker cdn105 Detected as cdn Wrong 15
With both: Speaker cdn105 Detected as cdn Wrong 4

With liftered cepstrum: Speaker cdn107 Detected as cdn Wrong 4
With acceleration: Speaker cdn107 Detected as cdn Wrong 15
With both: Speaker cdn107 Detected as cdn Wrong 4

With liftered cepstrum: Speaker cdn122 Detected as cdn Wrong 4
With acceleration: Speaker cdn122 Detected as cdn Wrong 15
With both: Speaker cdn122 Detected as cdn Wrong 4

With liftered cepstrum: Speaker cdn126 Detected as cdn Wrong 4
With acceleration: Speaker cdn126 Detected as cgy Wrong 16
With both: Speaker cdn126 Detected as cdn Wrong 4

With liftered cepstrum: Speaker cdn135 Detected as cdn Wrong 4
With acceleration: Speaker cdn135 Detected as chn Wrong 17
With both: Speaker cdn135 Detected as cdn Wrong 4

With liftered cepstrum: Speaker cdn139 Detected as cdn Wrong 4
With acceleration: Speaker cdn139 Detected as chn Wrong 18
With both: Speaker cdn139 Detected as cdn Wrong 4

With liftered cepstrum: Speaker cdt183 Detected as cdt Wrong 4
With acceleration: Speaker cdt183 Detected as chn Wrong 19
With both: Speaker cdt183 Detected as cdt Wrong 4

With liftered cepstrum: Speaker cdt187 Detected as cdt Wrong 4
With acceleration: Speaker cdt187 Detected as chn Wrong 20
With both: Speaker cdt187 Detected as cdt Wrong 4

With liftered cepstrum: Speaker cdt198 Detected as cdt Wrong 4
With acceleration: Speaker cdt198 Detected as chn Wrong 21
With both: Speaker cdt198 Detected as cdt Wrong 4

With liftered cepstrum: Speaker cdt237 Detected as cdt Wrong 4
With acceleration: Speaker cdt237 Detected as chn Wrong 22
With both: Speaker cdt237 Detected as cdt Wrong 4

With liftered cepstrum: Speaker cdv078 Detected as cdv Wrong 4
With acceleration: Speaker cdv078 Detected as cdv Wrong 22
With both: Speaker cdv078 Detected as cdv Wrong 4
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With liftered cepstrum: Speaker cdv080 Detected as cdv Wrong 4
With acceleration: Speaker cdv080 Detected as cdv Wrong 22
With both: Speaker cdv080 Detected as cdv Wrong 4

With liftered cepstrum: Speaker cdv081 Detected as cdv Wrong 4
With acceleration: Speaker cdv081 Detected as chn Wrong 23
With both: Speaker cdv081 Detected as cdv Wrong 4

With liftered cepstrum: Speaker cdv095 Detected as cdv Wrong 4
With acceleration: Speaker cdv095 Detected as chn Wrong 24
With both: Speaker cdv095 Detected as cdv Wrong 4

With liftered cepstrum: Speaker cdw131 Detected as cdw Wrong 4
With acceleration: Speaker cdw131 Detected as ccz Wrong 25
With both: Speaker cdw131 Detected as cdw Wrong 4

With liftered cepstrum: Speaker cdw142 Detected as cdw Wrong 4
With acceleration: Speaker cdw142 Detected as chn Wrong 26
With both: Speaker cdw142 Detected as cdw Wrong 4

With liftered cepstrum: Speaker cdw145 Detected as cdw Wrong 4
With acceleration: Speaker cdw145 Detected as chn Wrong 27
With both: Speaker cdw145 Detected as cdw Wrong 4

With liftered cepstrum: Speaker ceb014 Detected as ceb Wrong 4
With acceleration: Speaker ceb014 Detected as chn Wrong 28
With both: Speaker ceb014 Detected as ceb Wrong 4

With liftered cepstrum: Speaker ceb015 Detected as ceb Wrong 4
With acceleration: Speaker ceb015 Detected as chn Wrong 29
With both: Speaker ceb015 Detected as ceb Wrong 4

With liftered cepstrum: Speaker ceb022 Detected as cin Wrong 5
With acceleration: Speaker ceb022 Detected as chn Wrong 30
With both: Speaker ceb022 Detected as ceb Wrong 4

With liftered cepstrum: Speaker cel188 Detected as cel Wrong 5
With acceleration: Speaker cel188 Detected as cel Wrong 30
With both: Speaker cel188 Detected as cel Wrong 4

With liftered cepstrum: Speaker cel190 Detected as cel Wrong 5
With acceleration: Speaker cel190 Detected as chn Wrong 31
With both: Speaker cel190 Detected as cel Wrong 4

With liftered cepstrum: Speaker cel192 Detected as cel Wrong 5
With acceleration: Speaker cel192 Detected as chn Wrong 32
With both: Speaker cel192 Detected as cel Wrong 4

With liftered cepstrum: Speaker cel202 Detected as cel Wrong 5
With acceleration: Speaker cel202 Detected as cgy Wrong 33
With both: Speaker cel202 Detected as cel Wrong 4

With liftered cepstrum: Speaker cel220 Detected as cel Wrong 5
With acceleration: Speaker cel220 Detected as ckb Wrong 34
With both: Speaker cel220 Detected as cel Wrong 4

With liftered cepstrum: Speaker cem128 Detected as chj Wrong 6
With acceleration: Speaker cem128 Detected as chn Wrong 35
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With both: Speaker cem128 Detected as chj Wrong 5

With liftered cepstrum: Speaker cem131 Detected as cel Wrong 7
With acceleration: Speaker cem131 Detected as chj Wrong 36
With both: Speaker cem131 Detected as cel Wrong 6

With liftered cepstrum: Speaker cem137 Detected as chy Wrong 8
With acceleration: Speaker cem137 Detected as chn Wrong 37
With both: Speaker cem137 Detected as chy Wrong 7

With liftered cepstrum: Speaker cev090 Detected as cev Wrong 8
With acceleration: Speaker cev090 Detected as cic Wrong 38
With both: Speaker cev090 Detected as cev Wrong 7

With liftered cepstrum: Speaker cev092 Detected as cev Wrong 8
With acceleration: Speaker cev092 Detected as cic Wrong 39
With both: Speaker cev092 Detected as cev Wrong 7

With liftered cepstrum: Speaker cev094 Detected as cev Wrong 8
With acceleration: Speaker cev094 Detected as chn Wrong 40
With both: Speaker cev094 Detected as cev Wrong 7

With liftered cepstrum: Speaker cev101 Detected as cev Wrong 8
With acceleration: Speaker cev101 Detected as chn Wrong 41
With both: Speaker cev101 Detected as cev Wrong 7

With liftered cepstrum: Speaker cev112 Detected as cev Wrong 8
With acceleration: Speaker cev112 Detected as cev Wrong 41
With both: Speaker cev112 Detected as cev Wrong 7

With liftered cepstrum: Speaker cfi013 Detected as cfi Wrong 8
With acceleration: Speaker cfi013 Detected as cfi Wrong 41
With both: Speaker cfi013 Detected as cfi Wrong 7

With liftered cepstrum: Speaker cfi018 Detected as cfi Wrong 8
With acceleration: Speaker cfi018 Detected as cgy Wrong 42
With both: Speaker cfi018 Detected as cfi Wrong 7

With liftered cepstrum: Speaker cfi020 Detected as cfi Wrong 8
With acceleration: Speaker cfi020 Detected as cfi Wrong 42
With both: Speaker cfi020 Detected as cfi Wrong 7

With liftered cepstrum: Speaker cfi021 Detected as cfi Wrong 8
With acceleration: Speaker cfi021 Detected as cfi Wrong 42
With both: Speaker cfi021 Detected as cfi Wrong 7

With liftered cepstrum: Speaker cfi024 Detected as cfi Wrong 8
With acceleration: Speaker cfi024 Detected as cgy Wrong 43
With both: Speaker cfi024 Detected as cfi Wrong 7

With liftered cepstrum: Speaker cfj054 Detected as cfj Wrong 8
With acceleration: Speaker cfj054 Detected as chn Wrong 44
With both: Speaker cfj054 Detected as cfj Wrong 7

With liftered cepstrum: Speaker cfj055 Detected as cfj Wrong 8
With acceleration: Speaker cfj055 Detected as cgy Wrong 45
With both: Speaker cfj055 Detected as cfj Wrong 7
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With liftered cepstrum: Speaker cfj056 Detected as cfj Wrong 8
With acceleration: Speaker cfj056 Detected as chn Wrong 46
With both: Speaker cfj056 Detected as cfj Wrong 7

With liftered cepstrum: Speaker cfj057 Detected as cfj Wrong 8
With acceleration: Speaker cfj057 Detected as cgy Wrong 47
With both: Speaker cfj057 Detected as cfj Wrong 7

With liftered cepstrum: Speaker cfp027 Detected as cfp Wrong 8
With acceleration: Speaker cfp027 Detected as cfp Wrong 47
With both: Speaker cfp027 Detected as cfp Wrong 7

With liftered cepstrum: Speaker cfp043 Detected as cfp Wrong 8
With acceleration: Speaker cfp043 Detected as cfp Wrong 47
With both: Speaker cfp043 Detected as cfp Wrong 7

With liftered cepstrum: Speaker cfp048 Detected as cfp Wrong 8
With acceleration: Speaker cfp048 Detected as cfp Wrong 47
With both: Speaker cfp048 Detected as cfp Wrong 7

With liftered cepstrum: Speaker cfp058 Detected as cfp Wrong 8
With acceleration: Speaker cfp058 Detected as cfs Wrong 48
With both: Speaker cfp058 Detected as cfp Wrong 7

With liftered cepstrum: Speaker cfp061 Detected as cfp Wrong 8
With acceleration: Speaker cfp061 Detected as chn Wrong 49
With both: Speaker cfp061 Detected as cfp Wrong 7

With liftered cepstrum: Speaker cfs038 Detected as cfs Wrong 8
With acceleration: Speaker cfs038 Detected as cfs Wrong 49
With both: Speaker cfs038 Detected as cfs Wrong 7

With liftered cepstrum: Speaker cfs041 Detected as cfs Wrong 8
With acceleration: Speaker cfs041 Detected as cfs Wrong 49
With both: Speaker cfs041 Detected as cfs Wrong 7

With liftered cepstrum: Speaker cfs045 Detected as cfs Wrong 8
With acceleration: Speaker cfs045 Detected as cfs Wrong 49
With both: Speaker cfs045 Detected as cfs Wrong 7

With liftered cepstrum: Speaker cfu025 Detected as cfu Wrong 8
With acceleration: Speaker cfu025 Detected as cgy Wrong 50
With both: Speaker cfu025 Detected as cgx Wrong 8

With liftered cepstrum: Speaker cfu034 Detected as cfu Wrong 8
With acceleration: Speaker cfu034 Detected as cgy Wrong 51
With both: Speaker cfu034 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu043 Detected as cfu Wrong 8
With acceleration: Speaker cfu043 Detected as cgy Wrong 52
With both: Speaker cfu043 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu071 Detected as cfu Wrong 8
With acceleration: Speaker cfu071 Detected as cii Wrong 53
With both: Speaker cfu071 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu075 Detected as cfu Wrong 8
With acceleration: Speaker cfu075 Detected as cfj Wrong 54
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With both: Speaker cfu075 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu079 Detected as cfu Wrong 8
With acceleration: Speaker cfu079 Detected as cdi Wrong 55
With both: Speaker cfu079 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu089 Detected as cfu Wrong 8
With acceleration: Speaker cfu089 Detected as cii Wrong 56
With both: Speaker cfu089 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu095 Detected as cfu Wrong 8
With acceleration: Speaker cfu095 Detected as cii Wrong 57
With both: Speaker cfu095 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu099 Detected as cfu Wrong 8
With acceleration: Speaker cfu099 Detected as cfs Wrong 58
With both: Speaker cfu099 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu109 Detected as cfu Wrong 8
With acceleration: Speaker cfu109 Detected as cgy Wrong 59
With both: Speaker cfu109 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu112 Detected as cfu Wrong 8
With acceleration: Speaker cfu112 Detected as cgy Wrong 60
With both: Speaker cfu112 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfu116 Detected as cfu Wrong 8
With acceleration: Speaker cfu116 Detected as ceb Wrong 61
With both: Speaker.cfu116 Detected as cfu Wrong 8

With liftered cepstrum: Speaker cfx080 Detected as cfx Wrong 8
With acceleration: Speaker cfx080 Detected as chn Wrong 62
With both: Speaker cfx080 Detected as cfx Wrong 8

With liftered cepstrum: Speaker cfx088 Detected as cfx Wrong 8
With acceleration: Speaker cfx088 Detected as chn Wrong 63
With both: Speaker cfx088 Detected as cfx Wrong 8

With liftered cepstrum: Speaker cfx094 Detected as cfx Wrong 8
With acceleration: Speaker cfx094 Detected as cdn Wrong 64
With both: Speaker cfx094 Detected as cfx Wrong 8

With liftered cepstrum: Speaker cga092 Detected as cga Wrong 8
With acceleration: Speaker cga092 Detected as cdn Wrong 65
With both: Speaker cga092 Detected as cga Wrong 8

With liftered cepstrum: Speaker cga098 Detected as cga Wrong 8
With acceleration: Speaker cga098 Detected as chn Wrong 66
With both: Speaker cga098 Detected as cga Wrong 8

With liftered cepstrum: Speaker cga100 Detected as cga Wrong 8
With acceleration: Speaker cga100 Detected as cga Wrong 66
With both: Speaker cga100 Detected as cga Wrong 8

With liftered cepstrum: Speaker cga104 Detected as cga Wrong 8
With acceleration: Speaker cga104 Detected as cga Wrong 66
With both: Speaker cga104 Detected as cga Wrong 8
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With liftered cepstrum: Speaker cge113 Detected as cge Wrong 8
With acceleration: Speaker cge113 Detected as cge Wrong 66
With both: Speaker cge113 Detected as cge Wrong 8

With liftered cepstrum: Speaker cge117 Detected as cge Wrong 8
With acceleration: Speaker cge117 Detected as cge Wrong 66
With both: Speaker cge117 Detected as cge Wrong 8

With liftered cepstrum: Speaker cge120 Detected as cge Wrong 8
With acceleration: Speaker cge120 Detected as cge Wrong 66
With both: Speaker cge120 Detected as cge Wrong 8

With liftered cepstrum: Speaker cge122 Detected as cge Wrong 8
With acceleration: Speaker cge122 Detected as ccz Wrong 67
With both: Speaker cge122 Detected as cge Wrong 8

With liftered cepstrum: Speaker cgm168 Detected as cgm Wrong 8
With acceleration: Speaker cgm168 Detected as cgy Wrong 68
With both: Speaker cgm168 Detected as cgm Wrong 8

With liftered cepstrum: Speaker cgp007 Detected as cgp Wrong 8
With acceleration: Speaker cgp007 Detected as chn Wrong 69
With both: Speaker cgp007 Detected as cgp Wrong 8

With liftered cepstrum: Speaker cgp138 Detected as cgp Wrong 8
With acceleration: Speaker cgp138 Detected as ccv Wrong 70
With both: Speaker cgp138 Detected as cgp Wrong 8

With liftered cepstrum: Speaker cgp143 Detected as cch Wrong 9
With acceleration: Speaker cgp143 Detected as cfs Wrong 71
With both: Speaker cgp143 Detected as cgp Wrong 8

With liftered cepstrum: Speaker cgp152 Detected as cdn Wrong 10
With acceleration: Speaker cgp152 Detected as chn Wrong 72
With both: Speaker cgp152 Detected as cdn Wrong 9

With liftered cepstrum: Speaker cgp176 Detected as cch Wrong 11
With acceleration: Speaker cgp176 Detected as chn Wrong 73
With both: Speaker cgp176 Detected as cdn Wrong 10

With liftered cepstrum: Speaker cgx079 Detected as cgx Wrong 11
With acceleration: Speaker cgx079 Detected as cgx Wrong 73
With both: Speaker cgx079 Detected as cgx Wrong 10

With liftered cepstrum: Speaker cgx081 Detected as cgx Wrong 11
With acceleration: Speaker cgx081 Detected as chj Wrong 74
With both: Speaker cgx081 Detected as cgx Wrong 10

With liftered cepstrum: Speaker cgx096 Detected as cgx Wrong 11
With acceleration: Speaker cgx096 Detected as chs Wrong 75
With both: Speaker cgx096 Detected as cgx Wrong 10

With liftered cepstrum: Speaker cgy117 Detected as cgy Wrong 11
With acceleration: Speaker cgy117 Detected as cgy Wrong 75
With both: Speaker cgy117 Detected as cgy Wrong 10

With liftered cepstrum: Speaker chc098 Detected as cgx Wrong 12
With acceleration: Speaker chc098 Detected as chn Wrong 76
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With both: Speaker chc098 Detected as cii Wrong 11

With liftered.cepstrum: Speaker chg124 Detected as chg Wrong 12
With acceleration: Speaker chg124 Detected as chn Wrong 77
With both: Speaker chg124 Detected as chg Wrong 11

With liftered cepstrum: Speaker chg126 Detected as chg Wrong 12
With acceleration: Speaker chg126 Detected as chg Wrong 77
With both: Speaker chg126 Detected as chg Wrong 11

With liftered cepstrum: Speaker chg173 Detected as chg Wrong 12
With acceleration: Speaker chg173 Detected as chg Wrong 77
With both: Speaker chg173 Detected as chg Wrong 11

With liftered cepstrum: Speaker chg176 Detected as chg Wrong 12
With acceleration: Speaker chg176 Detected as chg Wrong 77
With both: Speaker chg176 Detected as chg Wrong 11

With liftered cepstrum: Speaker chg187 Detected as chg Wrong 12
With acceleration: Speaker chg187 Detected as chg Wrong 77
With both: Speaker chg187 Detected as chg Wrong 11

With liftered cepstrum: Speaker chg197 Detected as chg Wrong 12
With acceleration: Speaker chg197 Detected as chg Wrong 77
With both: Speaker chg197 Detected as chg Wrong 11

With liftered cepstrum: Speaker chg203 Detected as chg Wrong 12
With acceleration: Speaker chg203 Detected as chg Wrong 77
With both: Speaker chg203 Detected as chg Wrong 11

With liftered cepstrum: Speaker chg209 Detected as chg Wrong 12
With acceleration: Speaker chg209 Detected as chg Wrong 77
With both: Speaker chg209 Detected as chg Wrong 11

With liftered cepstrum: Speaker chj037 Detected as chj Wrong 12
With acceleration: Speaker chj037 Detected as chn Wrong 78
With both: Speaker chj037 Detected as chj Wrong 11

With liftered.cepstrum: Speaker chj039 Detected as chj Wrong 12
With acceleration: Speaker chj039 Detected as chn Wrong 79
With both: Speaker chj039 Detected as chj Wrong 11

With liftered cepstrum: Speaker chj043 Detected as chj Wrong 12
With acceleration: Speaker chj043 Detected as chn Wrong 80
With both: Speaker chj043 Detected as chj Wrong 11

With liftered cepstrum: Speaker chj044 Detected as chj Wrong 12
With acceleration: Speaker chj044 Detected as chj Wrong 80
With both: Speaker chj044 Detected as chj Wrong 11

With liftered cepstrum: Speaker chj052 Detected as chj Wrong 12
With acceleration: Speaker chj052 Detected as chj Wrong 80
With both: Speaker chj052 Detected as chj Wrong 11

With liftered cepstrum: Speaker chj206 Detected as chj Wrong 12
With acceleration: Speaker chj206 Detected as chn Wrong 81
With both: Speaker chj206 Detected as chj Wrong 11
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With liftered cepstrum: Speaker chj210 Detected as chj Wrong 12
With acceleration: Speaker chj210 Detected as chn Wrong 82
With both: Speaker chj210 Detected as chj Wrong 11

With liftered cepstrum: Speaker chj212 Detected as chj Wrong 12
With acceleration: Speaker chj212 Detected as chn Wrong 83
With both: Speaker chj212 Detected as chj Wrong 11

With liftered cepstrum: Speaker chj232 Detected as chj Wrong 12
With acceleration: Speaker chj232 Detected as chn Wrong 84
With both: Speaker chj232 Detected as chj Wrong 11

With liftered cepstrum: Speaker chj241 Detected as chj Wrong 12
With acceleration: Speaker chj241 Detected as ckb Wrong 85
With both: Speaker chj241 Detected as chj Wrong 11

With liftered cepstrum: Speaker chn110 Detected as chn Wrong 12
With acceleration: Speaker chn110 Detected as chn Wrong 85
With both: Speaker chn110 Detected as chn Wrong 11

With liftered cepstrum: Speaker chn116 Detected as chn Wrong 12
With acceleration: Speaker chn116 Detected as chn Wrong 85
With both: Speaker chn116 Detected as chn Wrong 11

With liftered cepstrum: Speaker chn118 Detected as chn Wrong 12
With acceleration: Speaker chn118 Detected as chn Wrong 85
With both: Speaker chn118 Detected as chn Wrong 11

With liftered cepstrum: Speaker chs072 Detected as chs Wrong 12
With acceleration: Speaker chs072 Detected as cdi Wrong 86
With both: Speaker chs072 Detected as chs Wrong 11

With liftered cepstrum: Speaker chs095 Detected as chs Wrong 12
With acceleration: Speaker chs095 Detected as chs Wrong 86
With both: Speaker chs095 Detected as chs Wrong 11

With liftered cepstrum: Speaker chs096 Detected as chs Wrong 12
With acceleration: Speaker chs096 Detected as cfs Wrong 87
With both: Speaker chs096 Detected as chs Wrong 11

With liftered cepstrum: Speaker chs109 Detected as cic Wrong 13
With acceleration: Speaker chs109 Detected as cfs Wrong 88
With both: Speaker chs109 Detected as cfs Wrong 12

With liftered cepstrum: Speaker chy130 Detected as chy Wrong 13
With acceleration: Speaker chy130 Detected as chn Wrong 89
With both: Speaker chy130 Detected as chy Wrong 12

With liftered cepstrum: Speaker cic140 Detected as cic Wrong 13
With acceleration: Speaker cic140 Detected as cfs Wrong 90
With both: Speaker cic140 Detected as cic Wrong 12

With liftered cepstrum: Speaker cic142 Detected as cic Wrong 13
With acceleration: Speaker cic142 Detected as cic Wrong 90
With both: Speaker cic142 Detected as cic Wrong 12

With liftered cepstrum: Speaker cic146 Detected as cic Wrong 13
With acceleration: Speaker cic146 Detected as chn Wrong 91
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With both: Speaker cic146 Detected as cic Wrong 12

With liftered cepstrum: Speaker cif074 Detected as cif Wrong 13
With acceleration: Speaker cif074 Detected as chn Wrong 92
With both: Speaker cif074 Detected as cif Wrong 12

With liftered cepstrum: Speaker cif076 Detected as cif Wrong 13
With acceleration: Speaker cif076 Detected as cgy Wrong 93
With both: Speaker cif076 Detected as cif Wrong 12

With liftered cepstrum: Speaker cif078 Detected as cif Wrong 13
With acceleration: Speaker cif078 Detected as cif Wrong 93
With both: Speaker cif078 Detected as cif Wrong 12

With liftered cepstrum: Speaker cif088 Detected as cif Wrong 13
With acceleration: Speaker cif088 Detected as chn Wrong 94
With both: Speaker cif088 Detected as cif Wrong 12

With liftered cepstrum: Speaker cif100 Detected as cif Wrong 13
With acceleration: Speaker cif100 Detected as ckb Wrong 95
With both: Speaker cif100 Detected as cif Wrong 12

With liftered cepstrum: Speaker cii102 Detected as cii Wrong 13
With acceleration: Speaker cii102 Detected as chn Wrong 96
With both: Speaker cii102 Detected as cii Wrong 12

With liftered cepstrum: Speaker cii104 Detected as cii Wrong 13
With acceleration: Speaker cii104 Detected as chn Wrong 97
With both: Speaker cii104 Detected as cii Wrong 12

With liftered cepstrum: Speaker cii109 Detected as cii Wrong 13
With acceleration: Speaker cii109 Detected as chn Wrong 98
With both: Speaker cii109 Detected as cii Wrong 12

With liftered cepstrum: Speaker cik182 Detected as cik Wrong 13
With acceleration: Speaker cik182 Detected as ckb Wrong 99
With both: Speaker cik182 Detected as chj Wrong 13

With liftered cepstrum: Speaker cik193 Detected as cik Wrong 13
With acceleration: Speaker cik193 Detected as cii Wrong 100
With both: Speaker cik193 Detected as cik Wrong 13

With liftered cepstrum: Speaker cik195 Detected as cik Wrong 13
With acceleration: Speaker cik195 Detected as cdt Wrong 101
With both: Speaker cik195 Detected as cik Wrong 13

With liftered cepstrum: Speaker cin013 Detected as cin Wrong 13
With acceleration: Speaker cin013 Detected as cin Wrong 101
With both: Speaker cin013 Detected as cin Wrong 13

With liftered cepstrum: Speaker cin023 Detected as cin Wrong 13
With acceleration: Speaker cin023 Detected as cin Wrong 101
With both: Speaker cin023 Detected as cin Wrong 13

With liftered cepstrum: Speaker cjl055 Detected as cjl Wrong 13
With acceleration: Speaker cjl055 Detected as chn Wrong 102
With both: Speaker cjl055 Detected as cjl Wrong 13
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With liftered cepstrum: Speaker cjl060 Detected as cjl Wrong 13
With acceleration: Speaker cjl060 Detected as cjl Wrong 102
With both: Speaker cjl060 Detected as cjl Wrong 13

With liftered cepstrum: Speaker ckb053 Detected as ckb Wrong 13
With acceleration: Speaker ckb053 Detected as ckb Wrong 102
With both: Speaker ckb053 Detected as ckb Wrong 13

With liftered cepstrum: Speaker ckb062 Detected as ckb Wrong 13
With acceleration: Speaker ckb062 Detected as ckb Wrong 102
With both: Speaker ckb062 Detected as ckb Wrong 13

With liftered cepstrum: Speaker ckb066 Detected as ckb Wrong 13
With acceleration: Speaker ckb066 Detected as cii Wrong 103
With both: Speaker ckb066 Detected as ckb Wrong 13

With liftered cepstrum: Speaker ckb071 Detected as cel Wrong 14
With acceleration: Speaker ckb071 Detected as ckb Wrong 103
With both: Speaker ckb071 Detected as ckb Wrong 13

With liftered cepstrum: Speaker ckb074 Detected as ckb Wrong 14
With acceleration: Speaker ckb074 Detected as ckb Wrong 103
With both: Speaker ckb074 Detected as ckb Wrong 13

With liftered cepstrum: Speaker ckb078 Detected as ckb Wrong 14
With acceleration: Speaker ckb078 Detected as ckb Wrong 103
With both: Speaker ckb078 Detected as ckb Wrong 13

With liftered cepstrum: Speaker ckc058 Detected as ckc Wrong 14
With acceleration: Speaker ckc058 Detected as chn Wrong 104
With both: Speaker ckc058 Detected as ckc Wrong 13

With liftered cepstrum: Speaker ckc067 Detected as ckc Wrong 14
With acceleration: Speaker ckc067 Detected as ckc Wrong 104
With both: Speaker ckc067 Detected as ckc Wrong 13

With liftered cepstrum: Speaker ckc069 Detected as ckc Wrong 14
With acceleration: Speaker ckc069 Detected as ckb Wrong 105
With both: Speaker ckc069 Detected as ckc Wrong 13

With liftered cepstrum: Speaker ckc077 Detected as ckc Wrong 14
With acceleration: Speaker ckc077 Detected as chn Wrong 106
With both: Speaker ckc077 Detected as ckc Wrong 13

With liftered cepstrum: Speaker ckd088 Detected as ckd Wrong 14
With acceleration: Speaker ckd088 Detected as ckd Wrong 106
With both: Speaker ckd088 Detected as ckd Wrong 13

With liftered cepstrum: Speaker ckd124 Detected as ckd Wrong 14
With acceleration: Speaker ckd124 Detected as chn Wrong 107
With both: Speaker ckd124 Detected as ckd Wrong 13

With liftered cepstrum: Speaker ckd133 Detected as ckd Wrong 14
With acceleration: Speaker ckd133 Detected as chn Wrong 108
With both: Speaker ckd133 Detected as ckd Wrong 13

percent correct liftered cepstrum = 91.194969
percent correct acceleration cepstrum = 32.075472
```



```
percent correct both = 91.823899
```

With RASTA-Liftered Cepstrum and Delta Cepstrum

```
With RASTA-lifterecl cepstrum: Speaker ccd064 Detected as cii Wrong 1
With delta: Speaker ccd064 Detected as ccd Wrong 0
With both: Speaker ccd064 Detected as ccd Wrong 0

With RASTA-lifterecl cepstrum: Speaker ccd078 Detected as cii Wrong 2
With delta: Speaker ccd078 Detected as ccz Wrong 1
With both: Speaker ccd078 Detected as cii Wrong 1

With RASTA-lifterecl cepstrum: Speaker ccd094 Detected as cii Wrong 3
With delta: Speaker ccd094 Detected as ccd Wrong 1
With both: Speaker ccd094 Detected as cii Wrong 2

With RASTA-lifterecl cepstrum: Speaker cch140 Detected as cch Wrong 3
With delta: Speaker cch140 Detected as cch Wrong 1
With both: Speaker cch140 Detected as cch Wrong 2

With RASTA-lifterecl cepstrum: Speaker cch142 Detected as cch Wrong 3
With delta: Speaker cch142 Detected as cch Wrong 1
With both: Speaker cch142 Detected as cch Wrong 2

With RASTA-lifterecl cepstrum: Speaker cch149 Detected as cch Wrong 3
With delta: Speaker cch149 Detected as cch Wrong 1
With both: Speaker cch149 Detected as cch Wrong 2

With RASTA-lifterecl cepstrum: Speaker ccv035 Detected as cjl Wrong 4
With delta: Speaker ccv035 Detected as cdn Wrong 2
With both: Speaker ccv035 Detected as cdn Wrong 3

With RASTA-lifterecl cepstrum: Speaker ccv039 Detected as ccv Wrong 4
With delta: Speaker ccv039 Detected as ccv Wrong 2
With both: Speaker ccv039 Detected as ccv Wrong 3

With RASTA-lifterecl cepstrum: Speaker ccv050 Detected as ccv Wrong 4
With delta: Speaker ccv050 Detected as cfs Wrong 3
With both: Speaker ccv050 Detected as ccv Wrong 3

With RASTA-lifterecl cepstrum: Speaker ccv052 Detected as ccv Wrong 4
With delta: Speaker ccv052 Detected as chn Wrong 4
With both: Speaker ccv052 Detected as ccv Wrong 3

With RASTA-lifterecl cepstrum: Speaker ccz041 Detected as ccz Wrong 4
With delta: Speaker ccz041 Detected as ccz Wrong 4
With both: Speaker ccz041 Detected as ccz Wrong 3

With RASTA-lifterecl cepstrum: Speaker ccz043 Detected as chc Wrong 5
With delta: Speaker ccz043 Detected as ccz Wrong 4
With both: Speaker ccz043 Detected as chc Wrong 4

With RASTA-lifterecl cepstrum: Speaker cdi009 Detected as cdi Wrong 5
With delta: Speaker cdi009 Detected as cdi Wrong 4
With both: Speaker cdi009 Detected as cdi Wrong 4

With RASTA-lifterecl cepstrum: Speaker cdi012 Detected as cdi Wrong 5
With delta: Speaker cdi012 Detected as cdi Wrong 4
With both: Speaker cdi012 Detected as cdi Wrong 4

With RASTA-lifterecl cepstrum: Speaker cdi022 Detected as cdt Wrong 6
With delta: Speaker cdi022 Detected as cdi Wrong 4
```



```
With both: Speaker cdi022 Detected as cdt Wrong 5

With RASTA-liftered cepstrum: Speaker cdk061 Detected as cdk Wrong 6
With delta: Speaker cdk061 Detected as cdk Wrong 4
With both: Speaker cdk061 Detected as cdk Wrong 5

With RASTA-liftered cepstrum: Speaker cdk063 Detected as cdk Wrong 6
With delta: Speaker cdk063 Detected as chn Wrong 5
With both: Speaker cdk063 Detected as cdk Wrong 5

With RASTA-liftered cepstrum: Speaker cdk065 Detected as cdk Wrong 6
With delta: Speaker cdk065 Detected as cdk Wrong 5
With both: Speaker cdk065 Detected as cdk Wrong 5

With RASTA-liftered cepstrum: Speaker cdn105 Detected as cdn Wrong 6
With delta: Speaker cdn105 Detected as cdn Wrong 5
With both: Speaker cdn105 Detected as cdn Wrong 5

With RASTA-liftered cepstrum: Speaker cdn107 Detected as cdn Wrong 6
With delta: Speaker cdn107 Detected as cdn Wrong 5
With both: Speaker cdn107 Detected as cdn Wrong 5

With RASTA-liftered cepstrum: Speaker cdn122 Detected as cdn Wrong 6
With delta: Speaker cdn122 Detected as cdn Wrong 5
With both: Speaker cdn122 Detected as cdn Wrong 5

With RASTA-liftered cepstrum: Speaker cdn126 Detected as cdn Wrong 6
With delta: Speaker cdn126 Detected as cdn Wrong 5
With both: Speaker cdn126 Detected as cdn Wrong 5

With RASTA-liftered cepstrum: Speaker cdn135 Detected as cdn Wrong 6
With delta: Speaker cdn135 Detected as cdn Wrong 5
With both: Speaker cdn135 Detected as cdn Wrong 5

With RASTA-liftered cepstrum: Speaker cdn139 Detected as cdn Wrong 6
With delta: Speaker cdn139 Detected as cdn Wrong 5
With both: Speaker cdn139 Detected as cdn Wrong 5

With RASTA-liftered cepstrum: Speaker cdt183 Detected as cdt Wrong 6
With delta: Speaker cdt183 Detected as cdt Wrong 5
With both: Speaker cdt183 Detected as cdt Wrong 5

With RASTA-liftered cepstrum: Speaker cdt187 Detected as chn Wrong 7
With delta: Speaker cdt187 Detected as chn Wrong 6
With both: Speaker cdt187 Detected as chn Wrong 6

With RASTA-liftered cepstrum: Speaker cdt198 Detected as cdt Wrong 7
With delta: Speaker cdt198 Detected as cel Wrong 7
With both: Speaker cdt198 Detected as cii Wrong 7

With RASTA-liftered cepstrum: Speaker cdt237 Detected as cdt Wrong 7
With delta: Speaker cdt237 Detected as chn Wrong 8
With both: Speaker cdt237 Detected as chn Wrong 8

With RASTA-liftered cepstrum: Speaker cdv078 Detected as cdv Wrong 7
With delta: Speaker cdv078 Detected as cgx Wrong 9
With both: Speaker cdv078 Detected as cdv Wrong 8
```

```
With RASTA-liftered cepstrum: Speaker cdv080 Detected as cdv Wrong 7
With delta: Speaker cdv080 Detected as ceb Wrong 10
With both: Speaker cdv080 Detected as cdv Wrong 8

With RASTA-liftered cepstrum: Speaker cdv081 Detected as ccz Wrong 8
With delta: Speaker cdv081 Detected as cii Wrong 11
With both: Speaker cdv081 Detected as cdk Wrong 9

With RASTA-liftered cepstrum: Speaker cdv095 Detected as cdk Wrong 9
With delta: Speaker cdv095 Detected as cgy Wrong 12
With both: Speaker cdv095 Detected as cdv Wrong 9

With RASTA-liftered cepstrum: Speaker cdw131 Detected as cdw Wrong 9
With delta: Speaker cdw131 Detected as cdv Wrong 13
With both: Speaker cdw131 Detected as cdw Wrong 9

With RASTA-liftered cepstrum: Speaker cdw142 Detected as cdw Wrong 9
With delta: Speaker cdw142 Detected as cdw Wrong 13
With both: Speaker cdw142 Detected as cdw Wrong 9

With RASTA-liftered cepstrum: Speaker cdw145 Detected as cdw Wrong 9
With delta: Speaker cdw145 Detected as cdw Wrong 13
With both: Speaker cdw145 Detected as cdw Wrong 9

With RASTA-liftered cepstrum: Speaker ceb014 Detected as cii Wrong 10
With delta: Speaker ceb014 Detected as chn Wrong 14
With both: Speaker ceb014 Detected as cii Wrong 10

With RASTA-liftered cepstrum: Speaker ceb015 Detected as ckc Wrong 11
With delta: Speaker ceb015 Detected as ceb Wrong 14
With both: Speaker ceb015 Detected as ceb Wrong 10

With RASTA-liftered cepstrum: Speaker ceb022 Detected as cin Wrong 12
With delta: Speaker ceb022 Detected as cgx Wrong 15
With both: Speaker ceb022 Detected as ceb Wrong 10

With RASTA-liftered cepstrum: Speaker cel188 Detected as cgm Wrong 13
With delta: Speaker cel188 Detected as cel Wrong 15
With both: Speaker cel188 Detected as cel Wrong 10

With RASTA-liftered cepstrum: Speaker cel190 Detected as cgp Wrong 14
With delta: Speaker cel190 Detected as chn Wrong 16
With both: Speaker cel190 Detected as chn Wrong 11

With RASTA-liftered cepstrum: Speaker cel192 Detected as cev Wrong 15
With delta: Speaker cel192 Detected as cel Wrong 16
With both: Speaker cel192 Detected as cgp Wrong 12

With RASTA-liftered cepstrum: Speaker cel202 Detected as ckd Wrong 16
With delta: Speaker cel202 Detected as cin Wrong 17
With both: Speaker cel202 Detected as cin Wrong 13

With RASTA-liftered cepstrum: Speaker cel220 Detected as cgm Wrong 17
With delta: Speaker cel220 Detected as cgy Wrong 18
With both: Speaker cel220 Detected as cin Wrong 14

With RASTA-liftered cepstrum: Speaker cem128 Detected as chn Wrong 18
With delta: Speaker cem128 Detected as chn Wrong 19
```



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With both: Speaker cem128 Detected as chn Wrong 15

With RASTA-liftered cepstrum: Speaker cem131 Detected as cev Wrong 19
With delta: Speaker cem131 Detected as cfs Wrong 20
With both: Speaker cem131 Detected as cev Wrong 16

With RASTA-liftered cepstrum: Speaker cem137 Detected as chn Wrong 20
With delta: Speaker cem137 Detected as chn Wrong 21
With both: Speaker cem137 Detected as chn Wrong 17

With RASTA-liftered cepstrum: Speaker cev090 Detected as ccz Wrong 21
With delta: Speaker cev090 Detected as cev Wrong 21
With both: Speaker cev090 Detected as cev Wrong 17

With RASTA-liftered cepstrum: Speaker cev092 Detected as ccz Wrong 22
With delta: Speaker cev092 Detected as cev Wrong 21
With both: Speaker cev092 Detected as cev Wrong 17

With RASTA-liftered cepstrum: Speaker cev094 Detected as cev Wrong 22
With delta: Speaker cev094 Detected as cev Wrong 21
With both: Speaker cev094 Detected as cev Wrong 17

With RASTA-liftered cepstrum: Speaker cev101 Detected as cev Wrong 22
With delta: Speaker cev101 Detected as cev Wrong 21
With both: Speaker cev101 Detected as cev Wrong 17

With RASTA-liftered cepstrum: Speaker cev112 Detected as cev Wrong 22
With delta: Speaker cev112 Detected as cev Wrong 21
With both: Speaker cev112 Detected as cev Wrong 17

With RASTA-liftered cepstrum: Speaker cfi013 Detected as cfi Wrong 22
With delta: Speaker cfi013 Detected as cfi Wrong 21
With both: Speaker cfi013 Detected as cfi Wrong 17

With RASTA-liftered cepstrum: Speaker cfi018 Detected as cfi Wrong 22
With delta: Speaker cfi018 Detected as cfi Wrong 21
With both: Speaker cfi018 Detected as cfi Wrong 17

With RASTA-liftered cepstrum: Speaker cfi020 Detected as cfi Wrong 22
With delta: Speaker cfi020 Detected as cfi Wrong 21
With both: Speaker cfi020 Detected as cfi Wrong 17

With RASTA-liftered cepstrum: Speaker cfi021 Detected as cfi Wrong 22
With delta: Speaker cfi021 Detected as cfi Wrong 21
With both: Speaker cfi021 Detected as cfi Wrong 17

With RASTA-liftered cepstrum: Speaker cfi024 Detected as cfi Wrong 22
With delta: Speaker cfi024 Detected as cfi Wrong 21
With both: Speaker cfi024 Detected as cfi Wrong 17

With RASTA-liftered cepstrum: Speaker cfj054 Detected as cfj Wrong 22
With delta: Speaker cfj054 Detected as cdi Wrong 22
With both: Speaker cfj054 Detected as cfj Wrong 17

With RASTA-liftered cepstrum: Speaker cfj055 Detected as cgy Wrong 23
With delta: Speaker cfj055 Detected as cfj Wrong 22
With both: Speaker cfj055 Detected as cgy Wrong 18
```

With RASTA-liftered cepstrum: Speaker cfj056 Detected as cgy Wrong 24
With delta: Speaker cfj056 Detected as cdn Wrong 23
With both: Speaker cfj056 Detected as cgy Wrong 19

With RASTA-liftered cepstrum: Speaker cfj057 Detected as cfj Wrong 24
With delta: Speaker cfj057 Detected as cfj Wrong 23
With both: Speaker cfj057 Detected as cfj Wrong 19

With RASTA-liftered cepstrum: Speaker cfp027 Detected as cfp Wrong 24
With delta: Speaker cfp027 Detected as cfp Wrong 23
With both: Speaker cfp027 Detected as cfp Wrong 19

With RASTA-liftered cepstrum: Speaker cfp043 Detected as cfp Wrong 24
With delta: Speaker cfp043 Detected as cfp Wrong 23
With both: Speaker cfp043 Detected as cfp Wrong 19

With RASTA-liftered cepstrum: Speaker cfp048 Detected as cfp Wrong 24
With delta: Speaker cfp048 Detected as cfp Wrong 23
With both: Speaker cfp048 Detected as cfp Wrong 19

With RASTA-liftered cepstrum: Speaker cfp058 Detected as cfp Wrong 24
With delta: Speaker cfp058 Detected as cfp Wrong 23
With both: Speaker cfp058 Detected as cfp Wrong 19

With RASTA-liftered cepstrum: Speaker cfp061 Detected as ckd Wrong 25
With delta: Speaker cfp061 Detected as cfp Wrong 23
With both: Speaker cfp061 Detected as cfp Wrong 19

With RASTA-liftered cepstrum: Speaker cfs038 Detected as cfs Wrong 25
With delta: Speaker cfs038 Detected as cfs Wrong 23
With both: Speaker cfs038 Detected as cfs Wrong 19

With RASTA-liftered cepstrum: Speaker cfs041 Detected as cfs Wrong 25
With delta: Speaker cfs041 Detected as cfs Wrong 23
With both: Speaker cfs041 Detected as cfs Wrong 19

With RASTA-liftered cepstrum: Speaker cfs045 Detected as cfs Wrong 25
With delta: Speaker cfs045 Detected as cfs Wrong 23
With both: Speaker cfs045 Detected as cfs Wrong 19

With RASTA-liftered cepstrum: Speaker cfu025 Detected as cfu Wrong 25
With delta: Speaker cfu025 Detected as cgx Wrong 24
With both: Speaker cfu025 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu034 Detected as cfu Wrong 25
With delta: Speaker cfu034 Detected as cfu Wrong 24
With both: Speaker cfu034 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu043 Detected as cfu Wrong 25
With delta: Speaker cfu043 Detected as cfu Wrong 24
With both: Speaker cfu043 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu071 Detected as cfu Wrong 25
With delta: Speaker cfu071 Detected as cii Wrong 25
With both: Speaker cfu071 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu075 Detected as cfu Wrong 25
With delta: Speaker cfu075 Detected as ceb Wrong 26

With both: Speaker cfu075 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu079 Detected as cfu Wrong 25
With delta: Speaker cfu079 Detected as cgy Wrong 27
With both: Speaker cfu079 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu089 Detected as cfu Wrong 25
With delta: Speaker cfu089 Detected as cfu Wrong 27
With both: Speaker cfu089 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu095 Detected as cfu Wrong 25
With delta: Speaker cfu095 Detected as cfu Wrong 27
With both: Speaker cfu095 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu099 Detected as cfu Wrong 25
With delta: Speaker cfu099 Detected as cgy Wrong 28
With both: Speaker cfu099 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu109 Detected as cfu Wrong 25
With delta: Speaker cfu109 Detected as cfu Wrong 28
With both: Speaker cfu109 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu112 Detected as cii Wrong 26
With delta: Speaker cfu112 Detected as cfu Wrong 28
With both: Speaker cfu112 Detected as cfu Wrong 19

With RASTA-liftered cepstrum: Speaker cfu116 Detected as cfi Wrong 27
With delta: Speaker cfu116 Detected as cgy Wrong 29
With both: Speaker cfu116 Detected as cfi Wrong 20

With RASTA-liftered cepstrum: Speaker cfx080 Detected as chn Wrong 28
With delta: Speaker cfx080 Detected as cfx Wrong 29
With both: Speaker cfx080 Detected as cfx Wrong 20

With RASTA-liftered cepstrum: Speaker cfx088 Detected as cfx Wrong 28
With delta: Speaker cfx088 Detected as cdn Wrong 30
With both: Speaker cfx088 Detected as cdn Wrong 21

With RASTA-liftered cepstrum: Speaker cfx094 Detected as cdn Wrong 29
With delta: Speaker cfx094 Detected as cdn Wrong 31
With both: Speaker cfx094 Detected as cdn Wrong 22

With RASTA-liftered cepstrum: Speaker cga092 Detected as cga Wrong 29
With delta: Speaker cga092 Detected as cga Wrong 31
With both: Speaker cga092 Detected as cga Wrong 22

With RASTA-liftered cepstrum: Speaker cga098 Detected as cga Wrong 29
With delta: Speaker cga098 Detected as cga Wrong 31
With both: Speaker cga098 Detected as cga Wrong 22

With RASTA-liftered cepstrum: Speaker cga100 Detected as cga Wrong 29
With delta: Speaker cga100 Detected as cga Wrong 31
With both: Speaker cga100 Detected as cga Wrong 22

With RASTA-liftered cepstrum: Speaker cga104 Detected as cga Wrong 29
With delta: Speaker cga104 Detected as cga Wrong 31
With both: Speaker cga104 Detected as cga Wrong 22

With RASTA-liftered cepstrum: Speaker cge113 Detected as cge Wrong 29
With delta: Speaker cge113 Detected as cge Wrong 31
With both: Speaker cge113 Detected as cge Wrong 22

With RASTA-liftered cepstrum: Speaker cge117 Detected as cge Wrong 29
With delta: Speaker cge117 Detected as cge Wrong 31
With both: Speaker cge117 Detected as cge Wrong 22

With RASTA-liftered cepstrum: Speaker cge120 Detected as cin Wrong 30
With delta: Speaker cge120 Detected as cge Wrong 31
With both: Speaker cge120 Detected as cge Wrong 22

With RASTA-liftered cepstrum: Speaker cge122 Detected as cge Wrong 30
With delta: Speaker cge122 Detected as cge Wrong 31
With both: Speaker cge122 Detected as cge Wrong 22

With RASTA-liftered cepstrum: Speaker cgm168 Detected as cgm Wrong 30
With delta: Speaker cgm168 Detected as cgm Wrong 31
With both: Speaker cgm168 Detected as cgm Wrong 22

With RASTA-liftered cepstrum: Speaker cgp007 Detected as cgp Wrong 30
With delta: Speaker cgp007 Detected as chn Wrong 32
With both: Speaker cgp007 Detected as cgp Wrong 22

With RASTA-liftered cepstrum: Speaker cgp138 Detected as cgp Wrong 30
With delta: Speaker cgp138 Detected as cfx Wrong 33
With both: Speaker cgp138 Detected as cgp Wrong 22

With RASTA-liftered cepstrum: Speaker cgp143 Detected as cgm Wrong 31
With delta: Speaker cgp143 Detected as cdi Wrong 34
With both: Speaker cgp143 Detected as cgp Wrong 22

With RASTA-liftered cepstrum: Speaker cgp152 Detected as cgm Wrong 32
With delta: Speaker cgp152 Detected as cgy Wrong 35
With both: Speaker cgp152 Detected as cgy Wrong 23

With RASTA-liftered cepstrum: Speaker cgp176 Detected as cgy Wrong 33
With delta: Speaker cgp176 Detected as cfs Wrong 36
With both: Speaker cgp176 Detected as cgy Wrong 24

With RASTA-liftered cepstrum: Speaker cgx079 Detected as cgx Wrong 33
With delta: Speaker cgx079 Detected as cgx Wrong 36
With both: Speaker cgx079 Detected as cgx Wrong 24

With RASTA-liftered cepstrum: Speaker cgx081 Detected as cgp Wrong 34
With delta: Speaker cgx081 Detected as cgx Wrong 36
With both: Speaker cgx081 Detected as cgx Wrong 24

With RASTA-liftered cepstrum: Speaker cgx096 Detected as chc Wrong 35
With delta: Speaker cgx096 Detected as cel Wrong 37
With both: Speaker cgx096 Detected as cgx Wrong 24

With RASTA-liftered cepstrum: Speaker cgy117 Detected as cgy Wrong 35
With delta: Speaker cgy117 Detected as cgy Wrong 37
With both: Speaker cgy117 Detected as cgy Wrong 24

With RASTA-liftered cepstrum: Speaker chc098 Detected as cdk Wrong 36
With delta: Speaker chc098 Detected as chc Wrong 37

With both: Speaker chc098 Detected as cdk Wrong 25

With RASTA-liftered cepstrum: Speaker chg124 Detected as chg Wrong 36
With delta: Speaker chg124 Detected as ccz Wrong 38
With both: Speaker chg124 Detected as chg Wrong 25

With RASTA-liftered cepstrum: Speaker chg126 Detected as chg Wrong 36
With delta: Speaker chg126 Detected as chg Wrong 38
With both: Speaker chg126 Detected as chg Wrong 25

With RASTA-liftered cepstrum: Speaker chg173 Detected as cdt Wrong 37
With delta: Speaker chg173 Detected as chg Wrong 38
With both: Speaker chg173 Detected as cdt Wrong 26

With RASTA-liftered cepstrum: Speaker chg176 Detected as chg Wrong 37
With delta: Speaker chg176 Detected as chg Wrong 38
With both: Speaker chg176 Detected as chg Wrong 26

With RASTA-liftered cepstrum: Speaker chg187 Detected as cdw Wrong 38
With delta: Speaker chg187 Detected as chg Wrong 38
With both: Speaker chg187 Detected as chg Wrong 26

With RASTA-liftered cepstrum: Speaker chg197 Detected as chg Wrong 38
With delta: Speaker chg197 Detected as chg Wrong 38
With both: Speaker chg197 Detected as chg Wrong 26

With RASTA-liftered cepstrum: Speaker chg203 Detected as cii Wrong 39
With delta: Speaker chg203 Detected as chg Wrong 38
With both: Speaker chg203 Detected as cii Wrong 27

With RASTA-liftered cepstrum: Speaker chg209 Detected as ccz Wrong 40
With delta: Speaker chg209 Detected as chg Wrong 38
With both: Speaker chg209 Detected as ccz Wrong 28

With RASTA-liftered cepstrum: Speaker chj037 Detected as chn Wrong 41
With delta: Speaker chj037 Detected as chj Wrong 38
With both: Speaker chj037 Detected as chn Wrong 29

With RASTA-liftered cepstrum: Speaker chj039 Detected as chj Wrong 41
With delta: Speaker chj039 Detected as chn Wrong 39
With both: Speaker chj039 Detected as chj Wrong 29

With RASTA-liftered cepstrum: Speaker chj043 Detected as chj Wrong 41
With delta: Speaker chj043 Detected as chj Wrong 39
With both: Speaker chj043 Detected as chj Wrong 29

With RASTA-liftered cepstrum: Speaker chj044 Detected as cgm Wrong 42
With delta: Speaker chj044 Detected as chj Wrong 39
With both: Speaker chj044 Detected as chj Wrong 29

With RASTA-liftered cepstrum: Speaker chj052 Detected as chj Wrong 42
With delta: Speaker chj052 Detected as chj Wrong 39
With both: Speaker chj052 Detected as chj Wrong 29

With RASTA-liftered cepstrum: Speaker chj206 Detected as chj Wrong 42
With delta: Speaker chj206 Detected as cgy Wrong 40
With both: Speaker chj206 Detected as chj Wrong 29

With RASTA-liftered cepstrum: Speaker chj210 Detected as chj Wrong 42
With delta: Speaker chj210 Detected as chj Wrong 40
With both: Speaker chj210 Detected as chj Wrong 29

With RASTA-liftered cepstrum: Speaker chj212 Detected as chn Wrong 43
With delta: Speaker chj212 Detected as chj Wrong 40
With both: Speaker chj212 Detected as chj Wrong 29

With RASTA-liftered cepstrum: Speaker chj232 Detected as chn Wrong 44
With delta: Speaker chj232 Detected as chj Wrong 40
With both: Speaker chj232 Detected as chn Wrong 30

With RASTA-liftered cepstrum: Speaker chj241 Detected as cdn Wrong 45
With delta: Speaker chj241 Detected as chj Wrong 40
With both: Speaker chj241 Detected as chn Wrong 31

With RASTA-liftered cepstrum: Speaker chn110 Detected as chn Wrong 45
With delta: Speaker chn110 Detected as chn Wrong 40
With both: Speaker chn110 Detected as chn Wrong 31

With RASTA-liftered cepstrum: Speaker chn116 Detected as chn Wrong 45
With delta: Speaker chn116 Detected as chn Wrong 40
With both: Speaker chn116 Detected as chn Wrong 31

With RASTA-liftered cepstrum: Speaker chn118 Detected as chn Wrong 45
With delta: Speaker chn118 Detected as cii Wrong 41
With both: Speaker chn118 Detected as chn Wrong 31

With RASTA-liftered cepstrum: Speaker chs072 Detected as cfx Wrong 46
With delta: Speaker chs072 Detected as chg Wrong 42
With both: Speaker chs072 Detected as cfx Wrong 32

With RASTA-liftered cepstrum: Speaker chs095 Detected as chs Wrong 46
With delta: Speaker chs095 Detected as chs Wrong 42
With both: Speaker chs095 Detected as chs Wrong 32

With RASTA-liftered cepstrum: Speaker chs096 Detected as cdn Wrong 47
With delta: Speaker chs096 Detected as chy Wrong 43
With both: Speaker chs096 Detected as cdn Wrong 33

With RASTA-liftered cepstrum: Speaker chs109 Detected as cii Wrong 48
With delta: Speaker chs109 Detected as chs Wrong 43
With both: Speaker chs109 Detected as ccz Wrong 34

With RASTA-liftered cepstrum: Speaker chy130 Detected as chy Wrong 48
With delta: Speaker chy130 Detected as chn Wrong 44
With both: Speaker chy130 Detected as chy Wrong 34

With RASTA-liftered cepstrum: Speaker cic140 Detected as cic Wrong 48
With delta: Speaker cic140 Detected as cic Wrong 44
With both: Speaker cic140 Detected as cic Wrong 34

With RASTA-liftered cepstrum: Speaker cic142 Detected as cic Wrong 48
With delta: Speaker cic142 Detected as cic Wrong 44
With both: Speaker cic142 Detected as cic Wrong 34

With RASTA-liftered cepstrum: Speaker cic146 Detected as chn Wrong 49
With delta: Speaker cic146 Detected as chn Wrong 45

With both: Speaker cic146 Detected as chn Wrong 35

With RASTA-liftered cepstrum: Speaker cif074 Detected as cif Wrong 49
With delta: Speaker cif074 Detected as cif Wrong 45
With both: Speaker cif074 Detected as cif Wrong 35

With RASTA-liftered cepstrum: Speaker cif076 Detected as cgy Wrong 50
With delta: Speaker cif076 Detected as chn Wrong 46
With both: Speaker cif076 Detected as cgy Wrong 36

With RASTA-liftered cepstrum: Speaker cif078 Detected as cif Wrong 50
With delta: Speaker cif078 Detected as cif Wrong 46
With both: Speaker cif078 Detected as cif Wrong 36

With RASTA-liftered cepstrum: Speaker cif088 Detected as cdw Wrong 51
With delta: Speaker cif088 Detected as cif Wrong 46
With both: Speaker cif088 Detected as cif Wrong 36

With RASTA-liftered cepstrum: Speaker cif100 Detected as cif Wrong 51
With delta: Speaker cif100 Detected as cif Wrong 46
With both: Speaker cif100 Detected as cif Wrong 36

With RASTA-liftered cepstrum: Speaker cii102 Detected as cii Wrong 51
With delta: Speaker cii102 Detected as cgx Wrong 47
With both: Speaker cii102 Detected as cii Wrong 36

With RASTA-liftered cepstrum: Speaker cii104 Detected as cii Wrong 51
With delta: Speaker cii104 Detected as cii Wrong 47
With both: Speaker cii104 Detected as cii Wrong 36

With RASTA-liftered cepstrum: Speaker cii109 Detected as cii Wrong 51
With delta: Speaker cii109 Detected as chn Wrong 48
With both: Speaker cii109 Detected as cii Wrong 36

With RASTA-liftered cepstrum: Speaker cik182 Detected as ccz Wrong 52
With delta: Speaker cik182 Detected as cgy Wrong 49
With both: Speaker cik182 Detected as chn Wrong 37

With RASTA-liftered cepstrum: Speaker cik193 Detected as cik Wrong 52
With delta: Speaker cik193 Detected as cik Wrong 49
With both: Speaker cik193 Detected as cik Wrong 37

With RASTA-liftered cepstrum: Speaker cik195 Detected as chc Wrong 53
With delta: Speaker cik195 Detected as chc Wrong 50
With both: Speaker cik195 Detected as chc Wrong 38

With RASTA-liftered cepstrum: Speaker cin013 Detected as cin Wrong 53
With delta: Speaker cin013 Detected as cfp Wrong 51
With both: Speaker cin013 Detected as cin Wrong 38

With RASTA-liftered cepstrum: Speaker cin023 Detected as cin Wrong 53
With delta: Speaker cin023 Detected as cin Wrong 51
With both: Speaker cin023 Detected as cin Wrong 38

With RASTA-liftered cepstrum: Speaker cjl055 Detected as cjl Wrong 53
With delta: Speaker cjl055 Detected as cjl Wrong 51
With both: Speaker cjl055 Detected as cjl Wrong 38

```
With RASTA-liftered cepstrum: Speaker cjl060 Detected as cjl Wrong 53
With delta: Speaker cjl060 Detected as cjl Wrong 51
With both: Speaker cjl060 Detected as cjl Wrong 38

With RASTA-liftered cepstrum: Speaker ckb053 Detected as ckb Wrong 53
With delta: Speaker ckb053 Detected as ckb Wrong 51
With both: Speaker ckb053 Detected as ckb Wrong 38

With RASTA-liftered cepstrum: Speaker ckb062 Detected as cgy Wrong 54
With delta: Speaker ckb062 Detected as ckb Wrong 51
With both: Speaker ckb062 Detected as ckb Wrong 38

With RASTA-liftered cepstrum: Speaker ckb066 Detected as ckb Wrong 54
With delta: Speaker ckb066 Detected as ckb Wrong 51
With both: Speaker ckb066 Detected as ckb Wrong 38

With RASTA-liftered cepstrum: Speaker ckb071 Detected as cch Wrong 55
With delta: Speaker ckb071 Detected as cdi Wrong 52
With both: Speaker ckb071 Detected as cch Wrong 39

With RASTA-liftered cepstrum: Speaker ckb074 Detected as ckb Wrong 55
With delta: Speaker ckb074 Detected as ckb Wrong 52
With both: Speaker ckb074 Detected as ckb Wrong 39

With RASTA-liftered cepstrum: Speaker ckb078 Detected as ckb Wrong 55
With delta: Speaker ckb078 Detected as ckb Wrong 52
With both: Speaker ckb078 Detected as ckb Wrong 39

With RASTA-liftered cepstrum: Speaker ckc058 Detected as cgp Wrong 56
With delta: Speaker ckc058 Detected as ckc Wrong 52
With both: Speaker ckc058 Detected as cdi Wrong 40

With RASTA-liftered cepstrum: Speaker ckc067 Detected as ckc Wrong 56
With delta: Speaker ckc067 Detected as ckc Wrong 52
With both: Speaker ckc067 Detected as ckc Wrong 40

With RASTA-liftered cepstrum: Speaker ckc069 Detected as ckc Wrong 56
With delta: Speaker ckc069 Detected as ckc Wrong 52
With both: Speaker ckc069 Detected as ckc Wrong 40

With RASTA-liftered cepstrum: Speaker ckc077 Detected as cfs Wrong 57
With delta: Speaker ckc077 Detected as ckc Wrong 52
With both: Speaker ckc077 Detected as ckc Wrong 40

With RASTA-liftered cepstrum: Speaker ckd088 Detected as ckd Wrong 57
With delta: Speaker ckd088 Detected as ckd Wrong 52
With both: Speaker ckd088 Detected as ckd Wrong 40

With RASTA-liftered cepstrum: Speaker ckd124 Detected as cin Wrong 58
With delta: Speaker ckd124 Detected as cin Wrong 53
With both: Speaker ckd124 Detected as cin Wrong 41

With RASTA-liftered cepstrum: Speaker ckd133 Detected as ckd Wrong 58
With delta: Speaker ckd133 Detected as ckd Wrong 53
With both: Speaker ckd133 Detected as ckd Wrong 41

percent correct RASTA-liftered cepstrum = 63.522013
percent correct delta cepstrum = 66.666667
```



```
percent correct both =74.213836
```

Appendix 8

Status Reports

1.0 Status Report 1

In the first status report we presented the results of the preliminary experiments we conducted with the Backpropagation network and the Real-Time Recurrent Learning (or Recurrent Backpropagation). During the reporting period covered by status 1 we also attempted to duplicate the results that Kao and his colleagues had recently reported. Those results were some of the best reported as of the beginning of this effort. We also investigated different windowing (liftering) functions and conducted several experiments with different training and testing intervals.

1.1 Previous Results

This section describes recent results in speaker identification in the open literature.

Rahim (1992), and Burr (1992) have reported recognition rates of over 98% in 48-50 speaker experiments using wideband, high signal-to-noise ratio (SNR) speech (TIMIT). In both cases, the investigators used the LPC derived cepstral representation of speech as input parameters to a vector quantizer as the classifier. However, recognition rates drop nearly 30 percentage points when narrowband telephone channel speech is tested (Burr, 1992). Burr found that by including the delta cepstrum, he could regain approximately 15% in performance for a total of about 85% recognition rate .

Kao. et al. (1992) have conducted an intensive comparative analysis of several front end features using a VQ classifier. Their baseline results were obtained using 20 cepstral coefficients derived from 14th order LPC coefficients for each voiced frame of speech. They used a 30 msec. Hamming windowed frame at a 20 msec. frame rate. The 50 speaker KING speech database was used in their analysis. The KING database has several recording and channel induced classes. There are a total of 10 sessions in which all 50 speakers are represented. Sessions 1-5 and sessions 6-10 were recorded using two different recording setups respectively. The two recording setups induced two distinct channel conditions

on the speech. Furthermore, 26 speakers were recorded at a site in San Diego, CA and the other 24 speakers were recorded at a site in Nutley, NJ. The Nutley recordings are much noisier than the San Diego recordings. The table below describes the results using sessions 1-5.

	San Diego	Nutley	All
Baseline	81.73%	35.00%	58.82%
BPL	85.58%	47.00%	66.67%
RASTA	91.35%	50.00%	71.08%
BPL & RASTA	94.23%	61.00%	77.94%

Table 1

BPL stands for bandpass liftering. The lifter $w(k)$ used is described as:

$$w(k) = 1 + h\sin(\pi k / L); \quad k = 1,2,\ldots,L; \quad h = L/2 \qquad (1)$$

Where L is the number of cepstral coefficients; in this case 20.

The RASTA (RelAtive SpecTrAl) process (Hermansky, et al., 1992) bandpass filters each cepstral channel. In other words, each cepstral channel $c_k(n)$ is convolved with the impulse response $h(n)$. The system function used was

$$H(z) = \frac{0.1(2.0 + 1.0z^{-1} - 1.0z^{-3} - 2.0z^{-4})}{z^{-4}(1 - .98z^{-1})} \qquad (2)$$

It is important to note that Kao, et al. found no improvement in performance using Hermansky's (1990) Perceptual Linear Predictive (with RASTA filtering) features.

1.2 Baseline Results

We chose to baseline the backpropagation classifier and the pervasively used generalized Lloyd's vector quantization (VQ) classifier with cepstral front end features early in this project to have a readily available comparative base. Algorithms that do not quickly meet baseline performance can rapidly be discounted without having to thoroughly test the algorithm.

Unless otherwise stated, the front end features used in all tests are 14th order LPC derived cepstral coefficients. The cepstral coefficients are derived from the predictor coefficients by the following recursive procedure:

$$C_i = -LPC_i - \sum_{k=1}^{i-1} \frac{i-k}{i} C_{i-k}\, LPC_k, \qquad i = 1,2,\ldots,N \tag{3}$$

were N is the LPC order. A 32 msec frame with a Hamming window at a 16 msec frame rate was used. Only voiced frames of speech were used for both training and testing. All signal processing was done with Entropic's ESPS/Waves speech processing software.

1.2.1Backpropagation: The first set of tests were performed with the backpropagation (BP) classifier, with training on the first 16 speakers of the KING database, sessions 1-3, and testing on the same group of speakers from sessions 4 and 5. In order to have an even amount of training data from each speaker, we found the speaker from a given session with the least number of voiced frames of speech and combined that number of voiced frames from each session. The result was 9.6 sec. (3.2 sec. from each session) of training from each speaker. We also chose 3.2 sec. of testing from sessions 4 and 5. In all cases we allowed the network to build evidence on a frame-by-frame basis for each test file before reporting results.

In the first test, we separated the speakers into four groups of four speakers each and trained four separate BP classifiers with each group. We tested the BP's ability to correctly classifying in-class speakers and its ability to reject out-of-class speakers with thresholding. The recognition rate for the four subnet classifier, each with 4 hidden nodes, was 40% with a 15.83% false alarm rate.

Next a BP network with 40 hidden nodes was trained on all 16 speakers and produced a recognition rate of 53.3%. These results were obtained after approximately 100 epochs.

The final BP experiment was performed by training the same 40 hidden node network on all voiced frames of sessions 1-3 and tested with all voiced frames from session 4 and 5 combined. The result was 50% recognition. It is interesting to examine the differences between this experiment and the previous one noted. When the network was trained with a balanced training set (9.6 sec./speaker) the correct speaker was typically in second or third place when the network erred. The wrong speakers chosen appeared to be chosen randomly. However, when using all the data in the sessions for training, a few speakers had much more training data than others. In fact, speaker 4 had 2-3 times more data than 50% of the other speakers. Under this condition, speaker 4 was chosen

erroneously in over 70% of the missclassifications with the number 2 and 3 pick ranked very nearly the same as if ranked by the amount of training data.

These results are consistent with many previous observations that the backpropagation network is computing the a-posteriori probability of a given event. That may be useful under certain conditions but it is detremental in this project because we may want to identify an individual with very high accuracy regardless of their probability of occurrence.

1.2.2 Real-Time Recurrent Learning: We made an initial test of the recurrent backpropagation network with the real-time current learning (RTRL) algorithm. A full description of the algorithm is found in Williams and Zipser (1989). The initial test was performed to see if the RTRL could indeed separate speakers from a temporal presentation of cepstral coefficients. The speech preprocessing performed was the same as previously described in this section except that we used only 3.2 sec. of training from session 1 and .5 sec of testing from session 2. The experiment was only for three speakers. The network correctly classified all three speakers upon testing. With this result, we now feel more comfortable performing extensive testing of the RTRL network. However, much has been written about the excessive training times required of recurrent networks and their difficulties in scaling up. These are important considerations for future work.

1.2.3 VQ Classifier: In a series of experiments using VQ we attempted to duplicate some of the results of Kao, et al. since these are the best results reported to date using the KING database. This implies that the RASTA-liftered cepstral coefficients are the features of choice for speaker-identification as of today. The speech preprocessing was the same as already discussed, except that we first scaled the data by 16 to get close to the maximum dynamic range of the 16 bit "short" data type used by ESPS/Waves. The KING database was quantized using 12 bits. We also removed the dc value of each file before computing the LPC coefficients. This improved the performance of ESPS's probability of voicing algorithm. We used 32 codeword codebooks for each speaker with the mean-squared error distortion measure. The following tables summarize the results.

Training sessions	Testing session 4	Testing session 5	Testing sessions 4&5

1-3, all	81.25%	68.75%	87.50%
1-3, 9.6 sec.	62.50%	62.50%	*
1-3, 1 sec.	69.00%	50.00%	*

Table 2

The next set of experiments were conducted with cepstral liftering. Cepstral liftering is simply the windowing of the cepstral coefficients with some function. The results shown are from a Hamming window lifter. A triangular lifter, cosine squared lifter, and sin lifter discussed previously did not improve the results that follow.

Training sessions	Testing session 4	Testing session 5	Testing sessions 4&5
1-3, all	87.75%	75.00%	93.75%
1-3, 9.6 sec.	62.50%	62.50%	*
1-3, 1 sec.	69.00%	56.25%	*

Table 3

We also conducted a 26 speaker experiment (the San Diego group) to compare directly with Kao's results. The most comparable results using the 14th order cepstral coefficients were obtained with a 40 codeword codebook. Kao used the 20th order cepstrum with 32 codewords per speaker. The following table shows these results.

Training sessions	Testing session 4	Testing session 5	Testing sessions 4&5
1-3, all	77.00%	69.00%	84.62%

Table 4

Our final experiment conducted in this period was of short speech segment training and testing using a Nellis Green Flag database recorded and provided by Rome Laboratory. The database consists of tactical Green Flag exercise transmissions from Nellis Air Force Base. From a nine speaker set from four different platforms (including an air traffic controller) the VQ classifier using

liftered cepstral coefficients correctly identified all nine speakers with only 6 sec. of training and 3 sec. of testing. The actual amount of training and testing data used was less than what is stated because the algorithm uses only voiced information as previously stated.

1.3 Conclusion

This section is a discussion of our interpretation of the recent results discussed in this report. By Rahim and Burr's results, we know that with stable, wideband channels with high signal-to-noise ratios spatial representations (cepstral) of individuals' speech are highly separable. This results in very high recognition rates with as many as 50 speakers. Under the ideal signal conditions used by Rahim and Burr, simple VQ techniques are sufficient. Indeed they can arguably be considered preferable to more sophisticated neural network techniques because VQ can be implemented in real-time with modern computer workstations without special hardware.

When signal conditions are less than ideal, as we find with telephone speech data that has been recorded over a period of weeks or months with different equipment, recognition rates are dramatically reduced. The recognition rates can be significantly improved by liftering and RASTAing cepstral coefficients. The cepstral coefficients seem to be the representation of choice to date. The cepstrum works nicely because it appears to separate channel information, vocal tract information, glottal excitation, and external high frequency harmonics along the quefrency axis. Perhaps this is why the lifter and RASTA processes improve the recognition rates as shown here because these processes attenuate channel information.

Given our results on BP performance, we do not recommend further testing with the algorithm. With long training times (approximately 5 hours) encountered with up to 50 hidden nodes, it makes little sense to look for a larger network that can equal the VQ performance. It remains to be seen whether other non-time-dependent neural networks such as SOAF or other more costly classifiers such as Kohonen's learning vector quantizer or Gaussian mixture models can significantly improve results. We also feel that given the complexities of the RTRL network, this network must significantly improve results before it is considered as a viable alternative to VQ approaches.

2.0 Status Report 2

During the period of performance of the second status report, we investigated and fully tested RASTA filtering of cepstral coefficients, RASTA PLP, RASTA PLP with lateral inhibition, and their derivatives. We first used codebook fusion or adjudication during that period as well. We also conducted further experiments in short segment training and testing from the KING and Green Flag databases. Finally, we investigate a process called lateral inhibition for noise reduction during the second period of performance.

2.1 RASTA PLP and Lateral Inhibition

Notwithstanding the putative benefits of the auditory-like processing of the PLP model (see Appendix 2), the PLP model lacks the important auditory mechanism of masking. We add the masking mechanism by incorporating lateral inhibition within the PLP process. Although, the masking phenomenon is believed to be caused by the mechanical properties of the basilar membrane, masking can be effectively modeled with lateral inhibition. Although lateral inhibition (LIN) does not account for masking, it is a common processing strategy (across species) used in all sensory systems, including the auditory system **(Knudsen, 1978; Shepherd, 1988). LIN performs several functions of which contrast enhancement and noise suppression are the most important for this investigation.

We model the LIN process by convolving the negative of the second derivative of the Gaussian with the spectrum of the signal. We use the following particular LIN function implementation:

$$H(k) = \left[1.0 - (k/N)^2\right]\exp\left[-(k/N)^2/2.0\right], \quad k = 1,2,\ldots,K \tag{4}$$

where K is the number of frequency elements in the spectrum and N determines the bandwidth of the function. The PLP and LIN processes were developed to introduce some observed biological phenomena in the auditory-like model. In keeping with this approach, care must be taken in increasing the bandwidth of

the LIN filters according to the critical band function, which is defined as ***(Zwicker & Terhardt, 1980)

$$W_C(f) = 25 + 75\left(1 + 1.4 f^2\right)^{0.69} \tag{5}$$

To incorporate LIN in the RASTA PLP process, one simply convolves $H(k)$ with the signal spectrum $P(k)$ [Appendix 2, (2)] prior to computing the critical band filter banks [Appendix 2, (4)].

The next section summarizes the results obtained from experiments using three main classes of acoustic representations: LPC cepstrum, RASTA PLP, and RASTA PLP with LIN.

2.2 KING Speaker Identification Test Results

The results reported in this section are based on the 26 speaker San Diego set of the 8 KHz version of the KING database. The generalized Lloyd's VQ algorithm was used for designing the classifiers for all experiments. A 40 codeword per codebook classifier was used for each speaker. A 32 msec frame (256 samples) with a Hamming window at a 16 msec frame rate was used on all speech signals prior to parameterization.

We investigated three main classes of parameters and their derivatives. These were the LPC cepstrum, the RASTA PLP, and the RASTA PLP with lateral inhibition. In the LPC cepstrum class, the following parameters were computed: the 14th order LPC cepstrum; the delta cepstrum, using a seven point linear regression; the liftered cepstrum, using a Hamming window lifter; the RASTA cepstrum; and the RASTA liftered cepstrum. The RASTA PLP class consisted of the following parameters: the RASTA PLP cepstrum, the RASTA PLP delta cepstrum, and the RASTA PLP acceleration cepstrum. These parameters were computed by Reeves computer program. The RASTA PLP with LIN class was similar to the RASTA PLP class but with lateral inhibition introduced as well.

We report on the combination of features that produced the best results for each of the major parameter classes previously defined. The LPC order for the LPC cepstrum class was 14, and the LPC order for both RASTA PLP classes was 12. In both cases increasing the LPC order did not increase performance with the

40 codeword codebooks for each speaker. LR cepstrum Table 5 refers to the cepstrum that has been liftered and RASTA filtered as well.

	LPC Cepstrum	RASTA PLP	RASTA PLP, LIN
Combination	liftered cepstrum, delta cepstrum, LR cepstrum	cepstrum, delta cepstrum, acceleration ceps.	cepstrum, delta cepstrum, acceleration ceps.
Speakers Misclassified	10 and 16	16 and 17	3, 9, 17
% Correct	92.3%	92.3%	88.5%

Table 5

The results we obtained in these experiments do not agree with the results recently reported by Kao and his associates (see last status report). Their baseline results on the 26 speaker San Diego group using the LPC cepstrum was 81.73% correct. They reported that the RASTA PLP procedure did not improve on this baseline. We obtained 88.5% correct with the RASTA PLP cepstrum alone. As can be seen from the previous table, this performance can be improved by using the delta and acceleration features as well. Kao also reported that RASTA filtering of the cepstrum increased performance to 91.35% correct, and RASTA filtering with liftering increased performance to 94.23%. Our results were 76.9% for RASTA filtering alone, and 73.1% for RASTA and liftering combined. We can not explain the differences between the two sets of results. Recent communications with Kao have not shed any light on the problem.

When we first reviewed the results produced by the disparate parameters, we found that each parameter space caused different errors in classification, as illustrated in Table 5. We found that the correct speaker, though improperly identified in a given parameter space, for example the liftered cepstrum, might have a very small MSE ratio in that space; however, the incorrectly chosen speaker in the liftered cepstrum space might have a very large MSE ratio in, say the RASTA cepstrum. When the results from the different parameter spaces were combined, improvements in the overall scores were produced. That is why seemingly poor individual results, such as RASTA filtering, combined with others increased overall performance.

In addition to testing the parameters previously discussed, we were tasked by the Rome Lab Speech Group to test LPC parameters alone, and filter bank representations of the spectrum. LPC features alone produced 46.2% correct recognition, a 14th order uniform filter bank representation also produced a 46.2% correct recognition score, and a 24th order mel filter bank representation produced 76.9% correct recognition. These results support the cepstrum (and its variations) as the feature of choice for speaker identification.

2.3 *Short Segment Training and Testing Results*

In this section, we describe short segment training and testing experiments performed on 20 speakers of the KING database and 17 speakers of the Green Flag database. The motivation for these experiments is to determine whether mission-by-mission on-line tactical training and tracking of speakers is possible. Our conjecture is that it is possible and the results reported in this section support that conjecture.

In order to reduce the possibility that we are not tracking the strong background acoustics of fighter aircraft, we first performed short segment experiments on the KING database. Although each session in that database has different telephone channel conditions, we believe those channel characteristics are well below the energy levels of the speech and therefore the chances that we are performing channel identification and not speaker identification are reduced. Furthermore, by performing separate tests for each of the sessions of the database we can be more confident that we are performing speaker identification.

For the first experiment we chose the first 20 speakers to have a total of 7 seconds (5 for training and the next 2 for testing) of voiced data in session 1. These speakers were 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 18, 20, 21, 22, 24, and 26. Speakers 3, 13, 17, 19, and 25 did not meet this criteria. For each session 1-5, we trained separate codebooks for each of the 20 speakers chosen with 5 seconds of voiced data (liftered cepstrum and delta cepstrum). We tested with the next 2 seconds of voiced data from within the same transmission (data file). The cumulative results for all 5 sessions was 89.36% correct with liftered cepstrum only and 95.74% correct with liftered cepstrum and delta cepstrum combined (through the adjudication procedure previously described). These are the combined results of 94 individual tests. It is interesting to note that not all

speakers in each session had a full two seconds of voiced data for testing. In session 2, speaker 2 only had 1.57 sec., speaker 9 had no test data available, speaker 16 had .13 sec., speaker 20 had 1.26 sec., and speaker 26 had only .1 sec. for testing. In session 3, speaker 5 had 1.34 sec., speaker 7 had no test data, speaker 9 had .75 sec., speaker 14 had .05 sec., and speaker 16 had 1.82 sec. of test data. In session 4 speakers 11 and 12 had no test data, and in session 5 speaker 4 had .86 sec., speaker 9 and 24 had no test data, speaker 10 had .24 sec., speaker 16 had .21 sec., and speaker 22 had .24 sec. of test data available.

In the next experiment we reduced the amount of training data to 3.2 seconds and 1.6 seconds for testing. As in the previous experiment, we used testing data from the same transmission as the training data. Only speaker 24 from session 5 had no test data available. All other speakers in all sessions had the 1.6 seconds of test data available. The combined result of 99 individual tests was 87.88% correct with liftered cepstrum only and 92.93% with combined liftered cepstrum and delta cepstrum.

The next set of experiments shed some light on the performance that is to be expected on tactical AF communications. In the previous status report we reported that we obtained 100% recognition in a nine speaker experiment with less than six seconds of actual training data and less than three seconds of actual testing data. The amount of voiced information extracted from these training and testing transmissions are less than 50% of the actual transmission length. We performed another Green Flag database experiment in this reporting period with 17 speakers. One to eight transmissions were available for the experiment for each of the 17 speakers. We arbitrarily used the first two transmissions for training and the rest of the transmissions for testing. Each speaker had at least one and up to eight test transmissions for testing. The longest combined training transmission was 7.69 seconds for speaker CCZ, and the shortest training transmission was 2.47 seconds for speaker CGA. The longest test transmission was 3.81 seconds for speaker CFU, and the shortest test transmission was 1.02 seconds. The combined result from 42 test transmissions was 92.86% with the liftered cepstrum representation and 90.48% with the liftered cepstrum and the delta cepstrum combined.

It is clear from the results reported in this subsection that mission-by-mission on-line tactical training and tracking of speakers is possible with very high

accuracy. However, further testing with more databases is required to verify this assertion.

3.0 Status Report 3

In this reporting period we conducted more short segment testing and training, and began a preliminary analysis of methods for open set testing. We also added the acceleration cepstrum as an additional feature in the LPC cepstrum group. We trained a new codebook for this feature for all speakers in the San Diego group, sessions 1-5; and combined the results of these new codebooks with the previously computed results. We also conducted an across the great divide experiment with the San Diego group. To satisfy Rome Lab's request for more short segment training and testing, we conducted a 37 speaker Greenflag experiment.

3.1 KING Database Experiments

In this section we report on further work conducted with the KING database. As shown on Table 5 in the previous status report, the result from a combination of the liftered cepstra, delta cepstra, and the RASTA-liftered cepstra was 92.3% for the 26 speaker San Diego group, sessions 1-5. We added acceleration cepstra features and adjudicated the results of codebooks trained with these new features with the previously computed feature codebooks. Speaker 10, which was previously misclassified, was now picked up with the added feature giving a new score of 96.2% correct. We computed the acceleration cepstra by running the delta cepstra features through the same linear regression algorithm used to compute the delta cepstra.

We also conducted an across the Great Divide experiment using the same San Diego group. We trained on sessions 1-3 and tested on sessions 9 and 10. We did not have time to compute the RASTA PLP with lateral inhibition features. Table 6 shows the best results of this experiment. LR cepstrum refers to the RASTA and liftered cepstrum.

	LPC Cepstrum	RASTA PLP
Combination	liftered cepstrum, delta cepstrum, acceleration cepstrum, LR cepstrum	cepstrum, delta cepstrum, acceleration cepstrum
Number of Speakers Misclassified	19	17
% Correct	26.9%	34.6%

Table 6

The results we obtained in these experiments again do not agree with the results recently reported by Kao and his associates (see last status report). Kao et al. reported 77.88% correct recognition on the same group with RASTA and liftering alone. The difference between their experiment and ours is that they also included a run using sessions 6-8 for training and sessions 4 and 5 for testing.

3.2 Green Flag Database Results

In this section we discuss the results of speaker identification tests we conducted from an expanded group from the Green Flag database. In addition to the 17 speakers previously trained and tested, we added an additional 20 speakers for a new training and testing session. The 37 speakers were in 8 different aircraft or were ground controllers. Table 7 identifies the number of speakers associated with each platform type.

As in the previous experiments, we trained on the first two transmissions and tested on all subsequent available transmissions from each speaker. The following tables describe the training and testing transmission length statistics for this data set. The speaker identification performance is shown in Table 12.

Note that RASTA filtering degraded overall performance. This result is consistent with the putative channel normalizing effects of RASTA filtering. Since we assume the acoustic background in the transmissions are helping to separate the different speakers, one would expect that channel normalization would degrade performance.

Speakers in Platforms

Number of Speakers	Platform Type
1	C130
9	F15
2	RF4C
11	F16
4	F4G
1	EA6
1	F117
4	A10
4	Towers

Table 7

Training Transmission Length Statistics For 37 Transmissions

stat	seconds
max	7.82
min	1.89
mean	4.37

Table 8

Training Transmission Lengths

Transmission Length (*tl*)	Number of Transmissions
$1.0 \leq tl < 2.0$	1
$2.0 \leq tl < 3.0$	4
$3.0 \leq tl < 4.0$	5
$4.0 \leq tl < 5.0$	8
$5.0 \leq tl < 6.0$	4
$6.0 \leq tl < 7.0$	0
$7.0 \leq tl < 8.0$	5
Total	37

Table 9

Test Transmission Length Statistics For 37 Transmissions

stat	seconds
max	6.75
min	0.49
mean	2.15

Table 10

Test Transmission Lengths

Transmission Length (*tl*)	Number of Transmissions
$0.0 \leq tl < 1.0$	6
$1.0 \leq tl < 2.0$	56
$2.0 \leq tl < 3.0$	29
$3.0 \leq tl < 4.0$	13
$4.0 \leq tl < 5.0$	4
$5.0 \leq tl < 6.0$	2
$6.0 \leq tl < 7.0$	1
Total	111

Table 11

Results

Feature	Correct
liftered cepstrum	76.58%
delta cepstrum	58.56%
acceleration cepstrum	56.76%
RASTA	37.84%
cepstrum & delta	82.88%
cepstrum, delta, & acceleration	83.78%
cepstrum, delta, & RASTA	81.08%

Table 12

3.3 *Approaches to the Open Set Problem*

In this section we review two possible approaches to the tactical communications open set speaker identification problem. The concept of operations assumed is on-line training of desired speakers and the subsequent tracking of these speakers on a mission-by-mission basis. Given this concept of operations, techniques such as the Nearest Neighbor approach used in ITT's speaker identification system are not possible. We also do not believe that building out of class models based on previously recorded data is the appropriate approach to investigate. There are two main reasons for this. The first has to do with channel considerations. Since the channel changes considerably from day to day, there is no way of determining whether the generated out-of-class set is meaningful giving a new day's channel conditions. Similarly, there is no way of knowing whether the speakers chosen for the out-of-class set will more closely match the real out-of-class set or the trained speaker set.

Ideally, one would want to generate rejection criteria based on the training data. This may be accomplished by the following approach, which is very similar to the Gaussian Mixture Model (GMM) approach used by MIT Lincoln Lab. The first step would be to generate VQ codebooks as before using the Lloyd's Generalized Algorithm. Each codeword in each speaker's codebook is now the mean of a multivariate Gaussian. A diagonal covariance matrix can then be computed by passing the training data through each codebook one final time. Boundaries for each multivariate Gaussian can then be determined by each Gaussian's variance. For example, if a data vector falls beyond the boundaries determined by some $\delta\mathbf{C}$, where $\mathbf{C}$ is the covariance (diagonal) matrix of each Gaussian, then that data vector is considered to be outside the desired class. If more data vectors of a particular transmission fall outside those boundaries than not, then the entire transmission is labeled as unknown or novel.

More precisely, we want to determine whether an input vector x belongs to class (speaker) s_i, where i is refers to the ith speaker. We do this by maximizing the likelihood $P(x|s_i)$. We assume that each speaker is modeled by a *mixture* of n multivariate Gaussians. The mean vectors and diagonal covariance matrixes of the Gaussians are determined by the VQ process previously described. Therefore, each speaker model is described as

$$f_j(x|s_i) = \frac{1}{\sqrt{(2\pi)^N \det \mathrm{C}_{s_i,j}}} \exp\left\{-\frac{1}{2}\left(x-\mu_{s_i,j}\right)^T \mathrm{C}_{s_i,j}^{-1}\left(x-\mu_{s_i,j}\right)\right\}, \quad j=1,2,\ldots,n \quad (6)$$

where N is the dimension of x; and $\mu_{s_i,j}$ and $\mathrm{C}_{s_i,j}$ are the mean vector and diagonal covariance matrix of the jth model Gaussian for speaker s_i respectively. In order to reduce the computations required in (6), we can take the natural log of (6), remove the minus sign within the exponential, and remove the constants in the denominator. The distance measure becomes

$$d(x,\mu_{s_i,j}) = \left(x-\mu_{s_i,j}\right)^T \mathrm{C}_{s_i,j}^{-1}\left(x-\mu_{s_i,j}\right) + \ln\left(\det \mathrm{C}_{s_i,j}^{-1}\right). \quad (7)$$

Since the exponential's minus sign has been removed, the speaker's model that *minimizes* equation (7) wins.

We need assign the diagonal of $\mathrm{C}_{s_i,j}$ to vector $\sigma_{s_i,j}$ in order to set the class boundaries as previously discussed. We define the boundary as

$$b(\delta_{s_i,j},\sigma_{s_i,j}) = \left(\delta_{s_i,j}\sigma_{s_i,j}\right)^T \mathrm{C}_{s_i,j}^{-1}\left(\delta_{s_i,j}\sigma_{s_i,j}\right) + \ln\left(\det \mathrm{C}_{s_i,j}^{-1}\right). \quad (8)$$

Finally, the decision rule becomes

$$\mathrm{X}\left(s^*\right) = \operatorname{argmin}\begin{cases} d\left(x,\mu_{s_i,j}\right), & \text{if } d\left(x,\mu_{s_i,j}\right) < b\left(\delta_{s_i,j},\sigma_{s_i,j}\right) \\ \infty, & \text{otherwise} \end{cases}. \quad (9)$$

If $\mathrm{X}\left(s^*\right)$ scores mostly ∞ for all vectors in a transmission, then the test speaker is labeled as an unknown speaker.

The other approach worth considering is to adapt the cohort method for determining output score thresholds. Once the training data set of desired speakers has been gathered, the out-of-class thresholds can be determined. This is accomplished by computing the average score for each speaker's model using the other speakers training data; we'll call these speakers the background set. In other words

$$d(x,\bar{\mu}_{s_i,j}) = \frac{1}{B}\sum_{k=1}^{B}\left(x-\mu_{s_k,j}\right)^T \mathrm{C}_{s_k,j}^{-1}\left(x-\mu_{s_k,j}\right) + \ln\left(\det \mathrm{C}_{s_k,j}^{-1}\right), \quad (10)$$

where B is the number of background speakers. The decision rule now becomes

$$\Theta\left(s^*\right) = d(x,\bar{\mu}_{s_i,j}) - d(x,\mu_{s_i,j}) \quad (11)$$

$$\begin{aligned} &\Theta\left(s^*\right) > \Delta \Rightarrow s^* \text{ detected} \\ &\Theta\left(s^*\right) < \Delta \Rightarrow \text{unknown speaker} \end{aligned} \quad (12)$$

3.4 Conclusion

During this reporting period we added another LPC cepstrum derived feature, the acceleration cepstrum, and found that its addition improved overall performance. We also conducted an expanded Greenflag database experiment with 37 speakers and obtained over 83% recognition rate with 111 test transmissions. Finally we conducted an initial analysis of two approaches to the open set problem.

4.0 Status Report 4

During the reporting period of this status report, we concentrated on conducting narrowband experiments with both the KING and GREENFLAG databases. In the Status Report dated May 24, 1993, we reported the results of short segment experiments we conducted with the narrow band portion of the KING database. We reran those experiments with the wideband data to try and minimize the effects of the channel. In addition, we made a modification to the early stages of the cepstrum and delta cepstrum algorithm that has improved overall performance.

4.1 Narrowband Experiments

In this section we report on the results of bandpass filtering all speech data to a 500 - 2500 Hz band. The motivation for this was to use the information in the speech waveform with the most amount of energy, and to remove everything else. Any channel information that dominates the speech, especially at the higher frequencies, will be attenuated or removed. The details of the bandpass filter design used are shown in Section 5.3.

As in previous KING database experiments, we computed the liftered cepstrum, the delta cepstrum (with a seven point linear regression), the acceleration cepstrum, and RASTA cepstrum of the 26 speaker San Diego group. However this time we bandpass filtered the 8 kHz sampled waveforms prior to parameterization.

Table 13 shows the results of most of the combinations of features. The results shown were obtained through feature adjudication as explained in previous reports. The features used were enumerated as follows: 1) liftered cepstrum, 2) delta cepstrum, 3) acceleration cepstrum, and 4) RASTA cepstrum.

Features	Number of Speakers Misclassified	Percent Correct
1	2	92.3%
2	16	38.5%
3	11	57.7%
4	5	80.8%
1&2	3	88.5%
1&3	3	88.5%
1&4	3	88.5%
1,2&3	3	88.5%
1,2&4	4	84.6%
1,3&4	4	84.6%
2&4	5	80.8%
3&4	6	76.9%
1,2,3,&4	4	84.6%

Table 13

It is evident from Table 13 that bandpass filtering only improved the separability of the liftered cepstrum. The new score obtained from the liftered cepstrum feature was 92.3% as opposed to 88.5% recognition without bandpass filtering. However, without bandpass filtering, the inclusion of the other three parameters increased the overall performance to 96.2%. This was not the case with bandpass filtering; the inclusion of the other features reduced overall performance.

Therefore, what we gained by bandpass filtering in one parameter space - the liftered cepstrum - we lost in the other parameter spaces. One can conclude that the derivative and RASTA filtering operations have a much greater effect on the frequency channels outside of the 500-2500 Hz band. Since the cepstrum gives information relating to the harmonics of the signal, and there is more energy in the speech signal in the low end of the spectrum than the high end, we posit that the derivative and RASTA processes have their greatest influence on the low end of the spectrum - below 500 Hz. More work is needed to verify this assumption.

We also performed narrow bandpass experiments with the GREENFLAG database. This was an important exercise since these experiments would shed

light on how important the background audio is in identifying such short segment transmissions.

We found that bandlimiting the transmissions of the GREENFLAG database produced an overall decrease in performance. The best performance previously reported with a 37 speaker closed set, with 111 test transmissions was approximately 84% correct. Upon bandlimiting the data with the filter described in Section 5.3, the overall performance dropped to approximately 75%.

This is an important finding. This verifies that the audio background is a significant component in these tests. The new performance is close to what was reported by Lincoln Laboratories in an experiment to determine the effects of the background on the overall performance. In that experiment the background was deconvolved from the speech waveform. The subsequent speaker identification performance was similar to what we obtained by bandpass filtering. These findings suggest that the mean training length of four seconds (of trained radio communicator's speech) is close to what is required for good performance. In other words, since we are achieving approximately 75% correct recognition by reducing the effects of the background audio and channel, we should be near the knee of the performance versus training time curve.

With such short training utterances the audio background or "context" is important additional information for short utterance speaker identification. The flip side to this finding is that if a speaker's subsequent transmission has characteristically different audio background statistics, a mismatch is much more likely. Of course, this is not a surprising result. When channel conditions are known to change significantly, the need to train with many examples of a speaker's speech *in the different channel conditions* is well understood. A very important distinction must be pointed out however: *The need for large amounts of training data is not required to adequately model the speaker; it is required to model the changes in the acoustic parameters induced by varying channel conditions.*

4.2 Upcoming Work

This status report concludes our requirements for all work under the original contract except for a final report. We will deliver the final report at the end of the extension of this program. During the extension period, we will investigate techniques for dealing with out-of-set speakers. In the previous status report, we

outlined two potential approaches. To start, we will investigate a simpler approach. This will be to find the average lowest mean square error scores of the N closest speakers to each speaker in the database and set a threshold proportional to that score. This is a good first start since the overall algorithm will not change with this approach. If the stated approach is not sufficient, then we will investigate the methods explained in the previous status report.

4. 3 Bandpass Filter Design

This appendix describes the bandpass filter design described in Section 2. The filter was implemented using Entropic's ESPS filter routine *iir_filt*. The following is a copy of the parameter file used to design the filter. The variables pass_band_loss and stop_band_loss are in defined in dB. The variables s_freq1 and s_freq2 are the stopband frequencies and p_freq1 and p_freq2 define the passband frequencies. The other variables are self explanatory.

```
float samp_freq = 8000;
float gain = 1.0;
string filt_method = "BUTTERWORTH";
string filt_type = "BP";
float pass_band_loss = 3;
float stop_band_loss = 7;
float s_freq1 = 400;
float p_freq1 = 500;
float p_freq2 = 2500;
float s_freq2 = 2600;
```

The following are the filter polynomial coefficients and their respective zero-pole values. These were produced from the ESPS routine *filtspec*. The zeros and poles are listed as complex valued numbers in the form *[real part, imaginary part]*.

```
Record 1: num_size: 15, denom_size: 15, zero_dim: 14, pole_dim: 8

re_num_coeff:
 0:  0.016587      0  -0.11611      0  0.34833
```

5:	0	-0.58055	0	0.58055	0
10:	-0.34833	0	0.11611	0	-0.016587

re_denom_coeff:

0:	1	-3.7875	6.4156	-7.2633	7.4114
5:	-6.9468	5.1075	-2.9843	1.6353	-0.80399
10:	0.28173	-0.073536	0.021143	-0.0041528	-1.447e-06

zeros:

0:	[-1,	0]	[1,	0]
2:	[-1,	0]	[1,	0]
4:	[-1,	0]	[1,	0]
6:	[-1,	0]	[1,	0]
8:	[-1,	0]	[1,	0]
10:	[-1,	0]	[1,	0]
12:	[-1,	0]	[1,	0]

poles:

0:	[-0.32454,	0.78778]	[0.86557,	0.35619]
2:	[-0.21493,	0.55368]	[0.75601,	0.29306]
4:	[-0.10124,	0.32377]	[0.64233,	0.20025]
6:	[-0.00034782,	0]	[0.54144,	0]

4.4 Improvements To Speaker Identification Algorithms Under Booz•Allen & Hamilton Investment

Booz•Allen is independently interested in speaker identification. Under Booz•Allen funding, the Principal Investigator worked for approximately one month to speed up the computation time of the speaker identification algorithms. In addition, an X window demonstration and interface was developed. These changes are described in this section.

A change in the up front processing stage has produced an unexpected performance improvement in the overall speaker identification performance. This occurred while trying to decrease overall processing time without degrading identification performance.

In the past, every frame in the transmission was processed (e.g., the cepstra, delta cepstra, and RASTA cepstra was computed for each frame). Afterwards, a voice, no-voice decision was made for each frame and only voiced frames of each parameter was kept for either training or testing. This appeared to be a tremendous waste in processing since most of the frames in an interval of natural speech is silence (or background). However, since the derivatives and RASTA filtering of the cepstral parameters is required in the process, it did not make sense to extract pieces of the transmissions and concatenate disjoint pieces of the communication.

Notwithstanding the *intuitive* reasons for not extracting the unvoiced sections of speech prior to further processing, we did it anyway and tested to see how it affected overall performance. We were surprised to find out that this method actually improved performance, and in some cases significantly.

With the new and faster algorithm we achieved 100% recognition of the San Diego group in the KING database. However the combination of features was different. The best performance prior to the algorithm change was 96.2% recognition with four features: liftered cepstra, delta cepstra, acceleration cepstra, and RASTA-liftered cepstra. With the new algorithm 100% recognition was achieved with the RASTA-liftered cepstra and the delta cepstra.

Even more significant results were obtained when we retested the GREENFLAG database. The best performance previously obtained was 83.78% recognition. With the faster algorithm we obtained nearly 95% recognition. In addition, Rome Laboratory provided us with additional speakers and transmissions, increasing the database to 41 speakers and a total of 159 test transmissions. We obtained nearly 94% recognition performance with the updated database in a new closed set test.

It is not entirely clear why the change to the algorithm previously described improves the overall recognition performance. What we know, however, is that the transition boundaries between the voiced and unvoiced sections of speech hamper the recognition process if included. We also know that the liftered cepstral features are identical in either process. What changes, of course, are the boundary areas in the delta, acceleration, and RASTA features. It appears that vocal tract transitions from voiced to voiced areas of speech are the important pieces of information vis-a-vis the derivative and filtering operations.

In addition to the algorithm change described above, we implemented the entire algorithm in C. The ESPS/Waves license is now not needed to run any of the speaker recognition functions developed to date. This has greatly decreased the computation time, however, we are not yet able to achieve real-time performance. The VQ training and testing portions of the algorithm require the most amount of time. We are implementing these algorithms on the Adaptive Solutions CNAPs SIMD parallel processor in order to achieve real-time training and testing. With this capability, we will be able to conduct many more tests in the upcoming program extension than we are now capable of performing.

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Appendix 9

Software User's Manual

Parameter Computation

All parameters are computed using four major C programs. These include:

a) *io_overlap.c*
b) *get_ceps.c*
c) *get_dceps.c*
d) *get_rasta.c*

The *io_overlap.c* program segments the sampled transmissions into overlapped frames of speech. The *get_ceps.c, get_dceps.c,* and the *get_rasta.c* programs compute the cepstrum, delta cepstrum, and RASTA cepstrum respectively.

At the C shell prompt, the programs are called as follows:

```
cat <file> | io_overlap <window width; in samples>  <amount of widow slide; \
in samples> | get_ceps <window width> <lpc order> <power_threshold>  \
<window?>   > <ceps file>
```

The argument <file> is the name of a raw binary input transmission file. If the input file has an Entropic header, then replace the cat <file> command with the following ESPS command: bhd <file.sd>. The bhd command strips the header from the input file. The last argument to the *get_ceps* program, <window?>, is a flag for liftering the cepstral coefficients; use 1 if you want the liftered cepstrum, 0 if you want the plain cepstrum. All other arguments are self explanatory.

To compute the delta cepstrum call *get_dceps* as follows:

```
cat <ceps file> | get_dceps <lpc order>  <buffer size>  <derivative points>   > \
<delta ceps file>
```

The argument <buffer size> refers to the number of cepstral vectors to read from the input stream and <derivative points> is the number of points to use for computing the regression. The call to the RASTA filtering program is similar:

```
cat <ceps file> | get_rasta <lpc order> <buffer size>   > <rasta ceps file>
```

Training

Once all the parameters have been obtained, train the codebooks for each parameter as follows:

```
lbg_vq <codebook file name> <parameter file> <lpc order> <codebook size> \
<converge threshold> <max iterations> <split criteria>
```

The argument <converge threshold> refers to the average codebook MSE change from the previous LBG iteration (see Appendix 4) and <max iterations> is the maximum number of LBG iterations allowed after each codeword split. The argument <split criteria> refers to the criteria for splitting individual codewords after binary codebook splitting is no longer possible. Use 0 for the density criterion and 1 for the MSE criterion.

Testing

For closed set testing use the program classify.c as follows:

```
cat <parameter file>  |  classify  <codebook file>   <lpc order> \
<codebook size>  <number of speakers>  >  <output file>
```

C Shell Scripts

To process many files in batch mode we used several C shell scripts in both KING and GREENFLAG experiments. In the top level KING directory we used make_all_params.csh, go_train.csh, and go_test.csh. These C shell programs iterate through the appropriate training and testing files and compute all parameters, train all codebooks, and finally process all test files.

Likewise, in the top level GREENFLAG directory, make_train_params.csh, make_test_params.csh, go_train.csh, and go_test.csh perform the functions named by the program. The go_test.csh program performs a closed-set test. There are several scripts that compute open-set tests using the different out-of-set criteria discussed in this report. The name of these scripts and the out-of-set metric they use follows:

a) *jack_knife.csh;* N Closest Speakers' Scores Thresholds

b) *jack_knife.thresh.cnaps.csh;* Global Thresholds

c) *jack_knife.cohort.cnaps.csh;* Cohort Normalized Thresholds

Scripts b) and c) call programs compiled on the CNAPS parallel processing server. The script *jack_knife.csh* calls the Sun workstation C programs we described in the previous sections of this Appendix. Any of the C shell scripts can be modified to process other databases in different directories.

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